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David Wright
Missouri University of Science and Technology, wrightmd@mst.edu

Daniel Burton Shank
Missouri University of Science and Technology, shankd@mst.edu

Thomas Yarbrough

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David Wright
Missouri University of Science and Technology
wrightmd@umsystem.edu

Daniel B. Shank
Missouri University of Science and Technology
shankd@umsyatem.edu

Thomas Yarbrough
Missouri University of Science and Technology
yarbrough@umsystem.edu

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David Wright
Missouri University of Science and Technology
wrightmd@umsystem.edu

Daniel B. Shank
Missouri University of Science and Technology
shankd@umsyatem.edu

Thomas Yarbrough
Missouri University of Science and Technology
yarbrough@umsystem.edu

ABSTRACT
While various forms of smart home technology have been available for decades, they have yet to achieve widespread adoption. Although they have risen in popularity during recent years, the general public continue to rate smart home devices as overly complex compared to their benefits. This article reports the results of an eight-month study into the effects of training on smart home technology adoption. Building upon the results of a previous study, and using the same living laboratory approach, we studied the effects of training on the attitudes of a group of residents toward use of smart home technology. Results show that training influences those attitudes toward smart home technology, including increased confidence in future use, and increased actual use of more complex smart home features. Results also indicate that users tended to seek out other users rather than training materials for advice, and that privacy concerns were not a deterrent to using smart home devices.

CCS Concepts
CCS → Social and professional topics → User characteristics

CCS → Human-centered computing

Keywords
Smart home technology, Training and Technology, Technology adoption, Technology diffusion, Usability

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INTRODUCTION
The role of training in Smart Home Technology (SHT) adoption has been largely overlooked because of assumptions that consumers will fully understand the technology's complex setup and myriad of potential uses after purchase. In this article, we present the findings of an eight-month study comparing the actions and attitudes of a trained group of SHT technology users in living laboratory houses against a previous cohort who lived in the same houses with the same technology but were not given training. We gain insight into details of the user's desires, use, lack of use, and effects of the training through ten themes that emerged from interviews conducted at the conclusion of the study. Our goal was not to examine particular training methods, nor technology acceptance on the basis of traditional diffusion models, but on the differential impact of training in this situation within the context of a network of smart home technologies.

While only a handful of SHT studies existed ten years ago, now there are dozens of studies on a variety of topics using different methodologies. However, studies that utilize a controlled environment to examine actual users of technology are still few in number. Most recent research focuses on buyer preferences and emotive reasoning for adoption rather than user experiences, training and usability. However, as Wilson et al. (2017) write,

> Analysis of reports, studies, websites and promotional material produced by smart home technology developers and service providers reveals a notable absence of user-focused research. User-oriented studies in actual smart home environments are notable exceptions rather than the rule. (p. 15)

Early SHT studies tended to focus on the technical specifications and interoperability rather than users (Hargreaves et al., 2018). But, in recent years, a more humanistic approach has become more popular. Many of the "first wave" humanistic studies focused on the perceived benefits of SHT among users or potential users. For example, users reported that they felt SHT could save energy and money (Mennicken & Huang, 2012; de Oliveira et al., 2015), enhance security (Brush et al., 2011; de Oliveira et al., 2015), save time (Mennicken & Huang, 2012; de Oliveira et al., 2015), and make life easier (Brush et al., 2011; de Oliveira et al., 2015). People also reported adopting SHT to feel technological (Mennicken & Huang, 2012; de Oliveira et al., 2015), to feel in control (Brush et al., 2011; Mennicken & Huang, 2012), or to feel modern (Mennicken & Huang, 2012). All of these benefits along with knowledge of SHTs continue to be highly related to their adoption and use (Shank, Wright, Lulham, & Thurgood, 2020). Later research shows that users want control over their home environment and products that are "designed to be reliable, easy to use, controllable, and easy to over-ride" (Wilson et al., 2017, p. 83) and that users, "do not want their home to be an unknown person with a mind of its own, but rather an intelligent helper that supports them to complete everyday tasks better or quicker while knowing when to leave inhabitants alone" (Mennicken et al., 2016, pp. 128–129).

Numerous models of technology acceptance have also been applied to SHT in an attempt to explain why users choose to adopt or reject it (Ahn et al., 2016; Yang et al., 2017; Nikou, 2019; Shuhaiber & Mashal, 2019; Baudier et al., 2020; Hubert et al., 2019). Those studies tend to show perceived ease of use and usefulness as primary drivers of adoption and perceived risks such as the time invested in learning to operate that technology (Wright & Shank, 2019) and giving up autonomy and control of the home (Wilson et al., 2017) as primary barriers to adoption. But, although SHT has been available for more than thirty years, it has failed to proliferate as expected (Brush et al., 2011; Fleishman, 2019). This has led some researchers to suggest that, "Smart home providers should survey user needs for their product instead of merely producing smart homes based on the design of the builder or engineer" (Luor et al., 2015, p. 377). Those perceptions do not seem to have changed much over time. According to Hargreaves and Wilson's 2017 book, 86% of survey respondents agreed that smart home technology is primarily designed to control energy, heating, and appliances. Those objectives do not line up with users' stated desires for controllable, intelligent systems that help them with everyday tasks (Hargreaves & Wilson, 2017; Mennicken et al., 2016). In fact, as Takahashi (2017) reported, 81% of consumers are aware of smart homes, but only 26% want one. This can be attributed to the discrepancy between their desires and their expectations or their understanding of the risks.

That discrepancy seems to have gone unnoticed by SHT manufacturers. As early as 2013, Balta-Ozkan et al. reported that a lack of knowledge, resistance to change, and the fact that users are not fully aware of their functions, potential risks and benefits was a major barrier to the proliferation of SHT. Hargreaves et al. (2018) agree, stating that complex learning demands placed on users are a strong detriment to utilizing smart home technology and that "there was little interest [among their respondents] in making use of the more advanced and automated features of the systems" (p. 134). Similar findings can be found in other research by Georgiev and Schlögl (2018) who found that insufficient interoperability, complexity, and lack of perceived value all hinder adoption of SHT; and research by de Oliveira et al. (2015) that shows SHT users are often overpowered by complex technology. These trends may have something to do with what Greenough (2016) refers to as the chasm of the technology adoption cycle, that space in between early adopter acceptance and widespread market acceptance. Greenough (2016) also mentions this is partially due to the poor interoperability between devices from different manufacturers, which makes advanced use difficult and complex.

That state of affairs has made marketing SHT difficult for manufacturers. While some have speculated that younger consumers or "digital natives" who have grown up with digital devices are more likely to use and purchase SHT, and might provide a better market for SHT, other research (Shin et al., 2018) finds older consumers to be more likely to adopt SHT within a given time frame. Also, some authors have convincingly argued that digital natives having superior technology skills is a myth (Selwyn, 2009; Margaryan et al., 2011; Kirschner & De Bruyckere, 2017). So, there is some discrepancy concerning the best potential market for SHT and digital natives cannot be counted as the "saviors" of SHT because of their mythical technology skills.

Regardless, the majority of the population between young and old are still in the "chasm" between the early adopters and the late adopters and have little experience with SHT or its (still) complex features. It is also true that privacy and security issues are still barriers to SHT adoption. Numerous articles have been written about the potential privacy abuses of SHT (Dorri et al., 2017; Geneiatakis et al., 2017; Mocrii et al., 2018) and of smart devices and cities in general (Zhang, et al., 2017; Gilliard, 2020). However, usability issues and a general lack of understanding may be a greater force in preventing its adoption. Zeng et al. (2017) found that users had some awareness of privacy issues but that their concerns were based more on physical security than information security. Likewise, Zheng et al. (2018) show that user's perceptions concerning information security are dependent upon their perceptions of the benefits they receive from those collecting information and that users generally trust manufactures to protect their privacy. In addition, Marikyan et al.'s (2019b) review of SHT literature shows, among other things, that a "usability barrier" created by problems with ease of use and reliability continues to be a major hindrance to widespread adoption. Likewise, Park et al. (2017) show that compatibility, connectedness and control are primary motivators for adoption. If this is true, then it stands to reason that a "usability barrier" surrounding SHT is primarily due to a lack of understanding concerning the operation and features of SHT.

Also, there is little support for users from manufacturers at this time. For example, Google and Samsung web sites promoting SHT focus mainly on the benefits of that technology and marketing in spite of the fact that users still:

- see SHT devices as complex and expensive (Georgiev & Schlögl, 2018)
- point to a lack of transparency from manufacturers and overpowering technology as major hindrances to adoption (de Oliveira et al., 2015)
- name ease of use of usefulness as highly important adoption factors (Nikou, 2019)
- cite overall risk perception as a distinct barrier to adoption (Hubert et al., 2019)

That risk can take many forms, including the risk associated with investing time into learning to use new devices that are often proprietary in nature (Wright & Shank, 2019). Thus, it stands to reason that in order to navigate the more complex features of SHT, users will require much more extensive and accessible support from manufacturers (or other sources) including the ability to repair or alter those devices. While some research (Vasisht et al., 2018; Cook et al., 2012) seeks to design "out of the box" smart homes or homes that can be more adaptively automated, other research (Yang et al., 2017) shows that automation has an insignificant impact on user attitudes toward SHT. So, while SHT may in fact become easier to use and more adaptive, users may always want to have a certain level of understanding and control over those devices. And, because it has been shown that the more individuals use a technology, the more they tend to use that technology in the future (Hew et al., 2015; Nikou & Bouwman, 2014), SHT users might benefit greatly from an initial training period that would get them using SHT devices more proficiently from the start and give them a feeling of control over those devices. If this is true, it could positively affect the process of adoption—thereby making the benefits of SHT more accessible to the average user.

Effects of Training on Technology

Training has been shown to have a positive impact on technology implementation in some theoretical constructs such as the Unified Theory of Acceptance and Use of Technology (UTAUT) (Marler et al., 2006; Marshall et al., 2008) which posits that users make decisions about technology adoption based on performance expectancy, effort expectancy, social influences, and facilitating conditions. However, studies concerning training and theories of technology acceptance such as the UTAUT, Technology Acceptance Model (TAM) and TAM2 are rare (Harris et al., 2018). Both TAM and TAM2 list perceived ease of use and perceived usefulness as factors in acceptance, and the latter includes social and cognitive factors. But those theories are typically applied to technology adoption independent of training considerations. So, while all of those theories have been very influential in technology adoption, their lack of emphasis on training as a factor in technology adoption limits their value in a training-based comparative study.

However, research in fields such as farming, education, and medicine does show a positive correlation between training and adoption (Nakano et al., 2018; T. Johnson et al., 2012; Mills & Olsen, 2008). Other studies (Durodolu, 2016) have suggested that training can be an effective tool for overcoming resistance to information technology systems. And finally, many articles (Mills & Harris, 2019; Dwivedi et al., 2017; Pynoo et al., 2011) suggest that organizations should provide proper training to users to enhance their willingness to use new technologies.

But training as a factor in technology implementation failure has also been well documented and is not well understood. As Harris et al. (2018) say, "There is widespread acknowledgement, by researchers and practitioners alike, that training is a critical factor in predicting technology acceptance and use. It is also clear that no model has effectively incorporated these features together" (p. 223). Previous research shows that a technological lack of understanding in fields such as the beef industry (Wright, 2015) can lead to rejection of new technology—especially digital or Internet of Things (IOT) technology. Dalcher and Genus (2003) report that approximately $150 billion are wasted each year in failed information systems implementations. Those failures occur globally and have been extensively documented in a variety of industries including port operations (Gekara & Nguyen, 2020), offshore construction (Boudreau & Holmström, 2011), and air traffic control (Genus et al., 2003). Each of those studies found inadequate training to be a factor in failure. Despite this, companies continue to invest heavily in both technology and training. In fact, as Bunch (2007) reports, although U.S. organizations spend over $200 billion annually on training, "much of this investment appears squandered on ill-conceived or poorly implemented interventions" (p. 142). Bunch (2007) goes on to show that training failure has been attributed to many different types of training including leadership, participation, quality management, and team development training.

Furthermore, while training has been shown to have a positive effect on technology adoption, training alone is not always effective for increasing its use and successful implementation in practical settings such as educational settings. Zhao and Bryant (2006) found that although training teachers on using classroom technology was effective at a basic level, training did not lead to higher levels of use, and participants requested extended mentoring in the future. Similarly, Davis (2002) found that one-on-one follow-up sessions with teachers led to higher levels of technology integration into classrooms after initial training sessions. Researchers in Brazil also found that instructors who had a higher perception of the impact of training were more likely to implement technology in their classrooms, indicating that even the perception of the quality of training can impact its use (Silva Farias & Mesquita Resende, 2020).

Thus, initial training sessions are not always enough to justify use over time, and when used as solitary incidents may cause abandonment of the technology before users have seen maximum benefit. That trend is not limited to digital or IOT technology. Researchers investigating physically assistive technology have found direct links between training and abandonment of the technology. For example, Sugawara et al. (2018) found that follow-up training with users of assistive technology was especially important in preventing abandonment. Likewise, Clawson et al. (2015) show that users of health-tracking technology often abandon that technology because of their inability to comfortably interact with their devices.

Finally, although studies connecting training and IOT technology use in "real" situations are rare and almost non-existent for SHT, some recent studies have spoken to the link. Jakobi et al. (2018) found that, even after training with smart home devices, study participants were only interested in receiving information from the system about things that had gone wrong after living with the devices for some time. That study also concluded that users with little experience with such technology were in effect made the system's administrator, and thus needed to see feedback tailored to their specific needs. In addition, Coskun et al. (2018) report that communicating SHT lifestyle improvements to users could be a key factor in acceptance—and is a matter of design and communication rather than marketing.

So, although training is an important factor in technology adoption and use, training has not been shown to guarantee acceptance and implementation of technology, and in some cases has been a part of the problem. Training has also not been effectively incorporated into theories of technology adoption. In any case, our focus here was not on the particular training methods used, but on the effects of general training on the use of SHT.

Prior Research

Our initial study (Wright & Shank, 2019), conducted over a period of eight months, was designed to find answers to two primary research questions.

1. How likely are residents to adopt SHT when they are provided with that technology but not provided with training

to accompany it?

2. How do residents provided with smart home technology learn to operate that technology?

Although participants initially rated the installed SHT quite highly and planned to use the devices, they also believed that the devices would have little impact on their lifestyle. As subjects lived with the devices over the next eight months, they continued to rate the devices highly but made little effort to learn about them. They also continued to rate their lifestyle impact as minimal. Residents did not make use of the more complex features of SHT and were largely unaware of device capabilities. Three primary reasons surfaced from our surveys and interviews with participants. First, smart home technology is still difficult to program, integrate and control. In determining whether to invest the time and energy necessary to learn programming and control (a risk), residents did not see enough potential reward. Second, because residents were given the technology without support for learning to operate that technology, they were unlikely to understand the technology and unlikely to grasp the full range of possible benefits. Third, the technical capabilities that were reported to be understood by residents *were* underwhelming and represented only minimal lifestyle enhancements for them (Wright & Shank, 2019).

Furthermore, from the perspective of models of technology diffusion and acceptance such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and use of Technology (UTAUT), perceived ease of use did not measure up to perceived usefulness, and social factors played little part in mediating that discrepancy. In short, effort expectancy exceeded performance expectancy. Survey comments revealed that without the training required to use the devices, residents did not believe that the potential benefits were worth the required time investment, which they viewed as the primary risk to adoption (Wright & Shank, 2019).

Current Research

In light of the findings above, our team decided to eliminate some of the obstacles faced by the previous subjects through a training orientation and support. By providing more informational support and training concerning the more complex operational features of the equipment, we sought to strengthen participants' understanding of the more potentially impactful lifestyle benefits of SHT. In doing so, our goal was to eliminate a simple lack of understanding as a barrier to SHT adoption and use. Therefore, for the current study, we sought to answer the following research questions:

1. Would training concerning the individual devices and more complex features of SHT change residents' perception of and use of SHT?

2. How would this data compare to the original research trial?

METHODS

To investigate these questions, we made investigative choices based on a pragmatic research paradigm, which prizes the research problem as the central focus and promotes, "methods most likely to provide insights into the question with no philosophical loyalty to any alternative paradigm" (Mackenzie & Knipe, 2006, p. 1). In doing so, we chose a mixed-methods approach that is well suited to gaining information about real-world problems (see R. B. Johnson & Onwuegbuzie, 2004; Creswell, 2003, pp. 155–179; Creswell & Creswell, 2017). Our method employed an exploratory sequential design (Driscoll et al., 2007; Rife, 2009; Fetters et al., 2013) by first collecting survey data and then using that data to inform the creation of specific interview questions in order to elicit high-quality, focused qualitative responses.

Study Environment

The Solar Village (Figure 1) on our campus consists of six solar houses constructed by student design teams between 2011 and 2017. We endeavored to equip all six houses with the following smart home technology:

- GE Z-Wave In-Wall Dimmer
- GE Z-Wave Smart Outlets
- Honeywell Wi-Fi Thermostat
- Schlage Connect Deadbolt
- Ring Video Doorbell
- Samsung Multipurpose Sensors
- Samsung Motion Sensors
- Samsung SmartThings Hub
- Netgear Nighthawk AC 1900 Smart Router
- Eufy Smart Bulbs (White)
- Eufy Smart Bulbs (Tunable)
- Amazon Echo
- Amazon Echo Dot

Figure 1: Four of the six solar village houses

While each house had most of these technologies, there were some minor differences in the number of devices and their setup due to building design differences. For example, not all houses were capable of supporting tunable light bulbs.

The devices can be controlled via voice commands (Amazon Echo), through installed cell phone apps, or manually. Therefore, participants can utilize the devices both within the house and remotely. Typical tasks might include turning on, off, or dimming lights, turning on or off devices plugged into outlets, controlling the thermostat, checking the doorbell video camera, and locking or unlocking doors.

Also, more complex functions (scenes) can be automated. For example, an alert can be sent by the multipurpose sensor to a cell phone if a door or window is unexpectedly opened. The same sensor is capable of automatically adjusting the thermostat in response to changes in temperature or humidity. Doors can be programmed to automatically lock at certain times or in response to sensors and can be locked or unlocked remotely. Motion sensors can be programmed to turn on individual lights or multiple lights in response to motion and can be set to do so at certain times if desired (e.g., only at night).

Users can also create scenes to operate multiple devices simultaneously. For example, the phrase, "Alexa I'm home," when spoken to the Echo device, might cause the front door to lock, the thermostat to adjust to 70 degrees, a television to turn on to a favorite channel or music station, a coffee pot to begin brewing, and lights to be set to 50% illumination. The phrase, "Alexa, movie time" might cause lighting to change to purple, for example, and Netflix to open on the television.

Solar Village Residents and SHT Training

There were a total of nine residents in the six houses, with three living alone and six living as housemate pairs. All residents were between the ages of 19 and 22 and enrolled full time at the university (which they must be to live in the village) in a variety of engineering majors. Residents must request to live in the houses and do so in return for reduced rent and paid utilities. They are also asked, though not required, to participate in university research. Therefore, although participants may be aware of SHT in the houses, their primary motivation for living in the village is its affordability.

At the beginning of the semester, we arranged for an SHT trainer (a member of our research team), to meet with residents of each household to discuss the devices installed in their respective homes. After introducing the technologies, the trainer provided more in-depth instruction (2–3 hours) that included:

- Giving the resident an interactive instructional PDF on SHT basics
- Assisting the resident in downloading all relevant cell phone applications
- Walking through the home to familiarize resident with device locations and functions
- Setting up the account names and passwords for their home profiles within the various applications
- Assigning permissions and application interfaces to allow for inter-system communications
- Demonstrating phone app automation naming (e.g., change "living room light" name to "ceiling fan light")
- Initializing primary setup of connected media accounts
    - Residents were provided an Amazon Prime account if they did not have one
    - Netflix was also installed and resident logged in to ensure initial functionality
- Demonstrating a pre-programmed "scene" (Alexa I'm Home) to elicit responses from the system. This was accompanied with showing resident where they could add additional functions to existing "scenes" within the application
- Assisting residents in setting up an individual "scene", in which a wake word or phrase would initiate a more complex system response
- Providing each resident with a folder in a private Google Drive which contained their username and password information in the event of control device loss
- Following up via email with the trainer's contact information, along with typical "if you have any questions" boilerplate

While there are numerous other technological/privacy issues that could have been covered in training, we chose to focus on these items because we were most interested in how users would learn about and use the SHT. Also, because of our IRB agreement, we were able to interview and survey residents but not able to visit the houses regularly or to collect data analytics. This was not an issue for our investigation, as we were mainly concerned with users' experience with the devices.

Surveys

The initial survey was administered in August 2019, while the monthly surveys (Appendix A) were administered from September 2019 through March 2020. We had originally planned to continue the surveys through May 2020, but the COVID virus forced most residents to move out of the village in March. In addition, four of the final monthly surveys were not completed. The surveys included both quantitative and qualitative questions and asked about the 10 most identifiable SHTs in their home (Power Monitoring Device, Environmental Sensors, Smart Home Hub Controller, Amazon Echo and/or Fire TV Cube, Smart Outlets, Motion Sensors, Smart Door Locks, Smart Thermostat, Smart Switches for Lights, Video Doorbell). For each survey, residents were asked to rate their use of and attitude toward each of the 10 devices on a seven-point scale with anchor phrases on each end for each concept (see Table 1). This is the same procedure used in the previous research1 (redacted for review) allowing us to make a direct comparison of the effects of training. Qualitative data was used to frame specific questions for interviews and is not presented separately.

Table 1: Primary SHT Measures in the Surveys

Concept Measured	Left Anchor Phrase (coded 1)	Right Anchor Phrase (coded 7)
Current Use	I have never used one	I often use one
Planned Use	I plan to not use this at all over the next month	I plan to use this often over the next month
Usefulness	I am uncertain of its usefulness	I am certain of its usefulness
Easy to Use	It seems difficult to use	It seems easy to use
Innovative	It is not innovative	It is innovative
Positivity	I feel negative about it	I feel positive about it
Sensitive Data	It does not involve sensitive data	It involves sensitive data
Know People Who Use	I do not know anyone who has one	I know many people who have one

Concept Measured	Left Anchor Phrase (coded 1)	Right Anchor Phrase (coded 7)
Beneficial	It is not be beneficial to me	It is beneficial to me
Dangerous	It is safe to use	It is not safe to use
Understandable	I do not understand it well	I do understand it well
Reliable	It is unreliable/ unpredictable	It is reliable/ predictable
Easy for Visitors	It is difficult for visitors to use	It is easy for visitors to use
Not a Privacy Con-cern	It is a privacy concern	It is not a privacy concern
Technology Compati-bility	It does not work well with other technology	It does work well with other tech-nology
Fit with Home	It does not fit well with my home	It does fit well with my home

Note: The last seven measures were only asked in monthly surveys. Beneficial had slightly different wording in the initial survey.

Interviews

After the surveys had been completed and a cursory analysis performed, a series of interview questions were developed to elicit more detailed responses from residents (Appendix B). Seven of the nine residents were interviewed individually[2] using Zoom during April and May. The interviews were informal in nature, but structured according to the questions listed in Appendix B. All interviews were recorded and kept on a private server for analysis. We began by looking for common themes among the responses by comparing responses from interviewees by question, then by participant, looking for themes and rhetorical similarities. We then grouped responses according to themes identified by a Thematic Content Analysis as part of intuitive inquiry, as described by Anderson (1998, 2007).

RESULTS

Quantitative Analysis from Surveys

First, we compared the mean ratings across all participants and devices for the previous study to the original study (Figure 2). Current use, planned use, usefulness, ease of use, innovativeness, positivity, benefit, understandability, reliability, ease of use for visitors, technological compatibility, and fit with home—all increased by at least 1 entire point the seven-point scale from the previous study to the current one. Additionally, residents in the current study reported the SHT seemed less dangerous (by 0.74) and involved less sensitive data (by 0.32). Residents were fairly similar (< 0.2 difference) in knowing people who use this technology and in their level of privacy concern about it. Across nearly all measure, the current study participants after receiving training reported greater use and more positive attitudes compared to participants just two years earlier with the same technology in the same houses, i.e., the previous study.

Next, we examine the distribution of ratings in the current study across product types to see if attitudes and use differ depending on SHT type (Figure 3). Both the current use and planned use for the next month display the same pattern with very different use

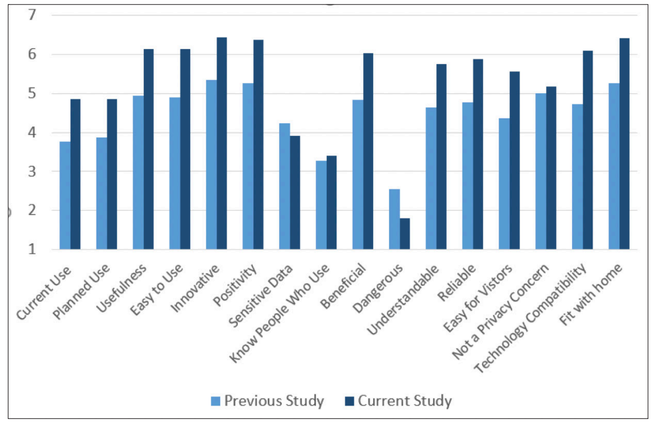

Figure 2: Reported Use and Attitudes Comparison between Studies

levels across products. The Amazon Echo, Smart Door Locks, and Smart Thermostat have the highest level of use and planned use. Smart Outlets, the Hub Controller, the Environmental Sensors, and the Power Monitoring Devices are at moderate levels of use and planned use. The Motion Sensors and Video Doorbell have low levels of use and planned use. Residents reported that the Amazon Echo, Smart Door Locks, the Hub Controller, and the Video Doorbell were moderately high in their use of sensitive data and therefore somewhat of a privacy concern. The remaining products clustered as being low in sensitive data and high in not being a privacy concern. Finally, on most of the other attitudes, there was not a strong difference or clustering by device.

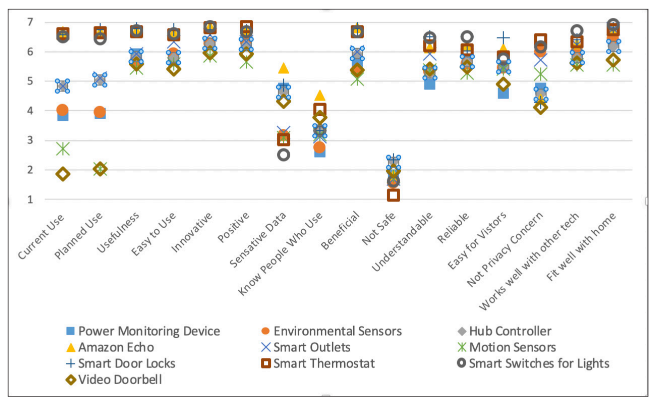

Figure 3: Reported Use and Attitudes Comparison among Devices in the Current Study.

Qualitative Analysis from Interviews

Our interviews added much needed depth allowing us to uncover ten rhetorical themes not available from the surveys.

First, most residents reported that the training was very helpful and that they understood much more after the training than prior to it. As one resident put it, "Before the training I had no idea what to do. After, I felt much more comfortable experimenting with the new stuff." Another resident reported that, "The training did help. It helped a ton to show us what we could do with it." Yet another resident reported that, "It really made things much faster to show us what we could do with it."

Second, residents also reported feeling much more comfortable with using SHT in their everyday lives. One resident reported liking, "being able to get ready in the morning without freezing" while knowing that their heating system was still being efficient. Others commented on liking having things connected and, "being able to turn off lights and things like that without getting distracted." Yet another resident said, "I used the automated locks the most. As soon as you walk in, it made me feel more secure. I'd say all of them are useful. It was just the matter of getting used to using them. The lights were useful."

Third, most residents had favorite items. Comments such as, "I like our thermostat. We can set like a range… just instead of having a constant turning it up or down," were common. Others reported that using their phones apps to control devices was most satisfying. Still others said, "Number one would be Alexa just because it makes it easier. If I had a preference, I would definitely say that what always caught my attention on the surface was the camera doorbell." Or, "Again, I like the thermostat because of the energy savings… and I still really like the idea of motion sensors." In general, the users reported much more interaction with the SHT devices and feeling more comfortable living with them. We were able to see a marked difference after training in their ability to take the initiative with SHT. Therefore, based on the inclusion of the training, the perception that it was helpful, and the higher levels of use and attitudes (Figure 2), we conclude that the training did enhance perception and use of the SHTs.

Fourth, they also felt that even more training would have been useful—especially, concerning sensors, more complex SHT functions, and phone applications. As one resident said, "I definitely knew a lot more after the training but I still didn't understand how to use a lot of the stuff like the sensors." In hindsight, it appears that although residents were much more capable than they had been with no training, even more training would have allowed them to move comfortably into the more complex aspects of SHT. In addition, some residents commented on the fact that they did not use the devices immediately after training but came back to them later. By that time, they wished that they still had access to training beyond the written documentation. As one person said, "I didn't really know my way around the apps then. I gave up on it." This suggests that it is not simply more or less training that makes a difference, but training as a time-sensitive scaffolding with different modes to help SHT users at the time they desire to understand and use new features of the technology. Different modes of information availability would also be helpful.

Fifth, residents were more likely to experiment with the more complex features of SHT devices after training and did feel more confident about its capabilities. Having devices connected was also more important to this group than we had observed in Study 1. They clearly enjoyed having more advanced features as an option and took more advantage of those features after training. This was especially true for lights, thermostats, door locks, and televisions.

Sixth, the Amazon Echo was widely regarded as the most useful item with its most common use related to SHT being to control lights within the houses and to control any scenes that had been developed during training or afterward. Its usefulness is understandable, because along with the installed cell phone app, it was the primary controller of SHT within the house and could also be used to answer simple everyday questions. One resident reported that, "Being able to make sure all of the lights were off through my phone was really nice." However, residents reported that they would have liked to have had more time and training to develop "scenes" for use in the houses. Two of the seven residents reported developing scenes to control multiple devices simultaneously, but most residents did not set up scenes, either because of a lack of time or because even after their training they did not feel fully competent in doing so. However, interviews show that most residents were unsure of how difficult it would be to set up scenes and therefore how much time might have to be invested. As a group, residents would also have liked more training with their phone applications.

Seventh, additional training probably would have helped most with the motion sensors and multipurpose sensors. Although most residents were intrigued by them after training, saying things such as, "I still really like the idea of the motion sensors," the prevalent theme among comments on these devices was that residents did not understand their capabilities, found them to be more complicated devices than the other SHT, and did not understand how to include them in scenes with other devices.

Eighth, as was true in our initial study, residents who did not take full advantage of SHT failed to do so because they were still unsure of what could be accomplished and how much time it would take to learn. Despite being more confident with the technology and more assured of its capabilities, some of the residents were unwilling to invest even a small amount of time into learning new skills that would have allowed them to do so much more with the equipment.

Ninth, residents also generally agreed that SHT would be more useful in a larger house. More specifically, and perhaps surprisingly, all but one resident plan to install SHT when they have a house of their own and they seem to intent on learning more about the technology at that time. One participant said, "I will definitely install SHT in my own house when I have one. I think it would be more useful then." That sentiment was shared by all but one of the interviewees, even though most only used the most basic features and devices available.

Tenth, residents, at least in their stage of life as a young adult and student, gained information only by asking other residents, asking friends or conducting simple web searches. They did not refer to the pdf file that was given to them. In general, most residents feel that SHT is still a little "difficult to get into." Interestingly, this particular group was not overly concerned about privacy issues or security, even though most acknowledge that SHT is still insecure in some ways. As one resident said, "I was never really concerned about Alexa. I know that there are a lot of privacy concerns with Alexa, but it was never really near the top of my mind." So, there seem to be fewer concerns with this group over privacy and security than with the first group, but almost all participants acknowledged that they still do not completely trust the devices to be secure or private.

DISCUSSION

Returning to our original research questions,

1. Would training concerning the individual devices and more complex features of SHT change residents' perception of and use of SHT?

2. How would this data compare to the original research trial?

The survey data and themes from the interviews clearly shows an upward trend concerning both use and perception for SHT. Residents were more aware of SHT capabilities and were more likely to experiment with and use SHT. In addition, survey data shows that residents had much more positive views of how SHT might impact their lifestyles after training. This alone is perhaps our most substantial result. It shows that training does impact both expected value and expected efforts in terms of SHT. Still, most residents did not take advantage of the more complex features of their SHT, even after training. We attribute this to three major issues. First, the skills needed to set up "scenes" with multiple devices or to use some of the more intricate devices such as motion and multi-purpose sensors were still beyond most of the residents. Second, they did not have access to the in-depth training after the original meeting. Third, interoperability issues and technical issues still caused some problems (Appendix C). Although most errors with the technology were overcome quickly, they can become an ongoing annoyance. Some of those issues were self-inflicted by users (forgetting what they had named particular lights or outlets) many others were completely out of their control. For example, an internet provider changing service parameters such as bandwidth allotment might cause a hub controller to cease functioning. Or, a general software update might cause an account to reset—thereby suspending service as well. The truth is that SHT devices are still not very easy to use, are highly proprietary, and "break" easily. Continual issues with service can become demoralizing and were not part of the training that was offered to residents.

So, it seems obvious now that the initial training helped greatly, but that even more extensive training would have been helpful, and that access to that training beyond the initial meeting would have been helpful as well. Also, training concerning device repair and operability may have been helpful, although this is somewhat specific to the device and issue causing a problem. It is worth noting that residents did still have access to the interactive PDF (Appendix D) file that they were given during their training, but that none of them mentioned returning to that document for troubleshooting. In terms of SHT they seemed unwilling to risk going beyond simple efforts to learn about SHT. This was especially true of household sensors, which were typically examined by residents and dismissed as too difficult to incorporate. In this light, it seems that a recorded video or web-based interactive demonstration of setting up the more complex aspect of SHT that could be accessed after the initial training enhance users' ability to fully utilize these technologies. As one resident put it, "Until you see these things in action you don't really know what they can do."

Because manufacturers still offer so little in terms of extended setup training, interoperability issues are still a problem between devices, and adoption rates among the general public remain low, training for new users seems imperative. YouTube videos abound on the subject, of course, but are often of questionable veracity, quality, and authenticity. Manufactures may be relying on those videos as a training source rather than producing their own content. But, due to the highly individualized nature of home environments and equipment combinations among the general public, those companies should begin to take a more active role in training their user base if they desire SHTs to proliferate.

Future Study and Limitations

The most obvious limitation of the study is its small sample size. Working with a controlled environment in a living laboratory setting has many advantages, such as being able to add standard technology for all residents whether they desire it or not as well as following up with ongoing surveys and a final interview. Also, the participants in this study were given SHT without asking for it. Therefore, their motivation to use the technology cannot be said to originate from personal desire, as might be found in a research sample that had purchased by choice. This may be important. For example, Clawson et al. (2015) found that only 5 of 23 users who abandoned physically assistive technology had purchased it. Additionally, Shank, Wright, Nasrin, and White (under review) found that those who were had been gifted an Alexa or smart home assistant often would completely disable it after a negative incident, whereas those who had purchased one would take less drastic actions like moving it to another room. Also, training that might include more emphasis on privacy issues might be beneficial. Although we did ask about privacy issues in our survey, and found that participants were not overly concerned, we cannot know what unnamed concerns may have been present.

Although all participants did show interest in using SHT on the initial survey, an interesting step forward might be to provide SHT to a greater number of research participants who indicate a desire for SHT before beginning the study. In that case their personal motivation could be established beforehand and the training variable more effectively isolated. Finally, more extensive and accessible training for users should be studied for impact.

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ENDNOTES

1. "Amazon Echo and/or Fire TV Cube" was only "Amazon Echo" in the previous research. The Fire TV Cube technology was added between studies.
2. Two residents, who were housemates and sisters, were interviewed together.

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ABOUT THE AUTHORS

David Wright is an Associate Professor in the English and Technical Communication department at Missouri University of Science and Technology. His teaching and research interests include smart home technology, usability studies, technology diffusion, and game studies.

Daniel B. Shank is an assistant professor in the Department of Psychological Science at Missouri Science & Technology. His current projects include investigating how people differently judge morality, mind, uncertainty, and affective impressions of actions, recommendations, and creations of AIs compared to those of humans. He currently has grants from the Army Research Office, the Leonard Wood Institute, and the National Science Foundation.

Thomas Yarbrough is a Senior Researcher for The Center for Research in Energy and Environment at Missouri University of Science and Technology. His research includes next-generation construction methods, home automation, sustainable technologies, and built environment integration.

APPENDIX A: ONGOING SURVEYS

Solar Village Ongoing Survey

Start of Block: Introduction

Q1 Technology Diffusion Patterns in Smart Living IRB 01-

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Informed Consent Form

Purpose: This research study is to find out how people use, adapt, think about, and change their behavior in response to living in a house with smart home technology. There are no expected risks for participation.

Procedures: If you agree to participate, you asked to complete a survey once a month. The initial survey will include demographic and general questions, and all of the surveys will ask about your use of the smart home technology and your day-to-day life and routines in the house. We anticipate each survey will take most people 10–25 minutes, depending on the length of response to the open-ended questions.

Voluntary Participation: Your participation in this study is completely voluntary, and you can skip any specific question without penalty or explanation. If desired, you are free to withdraw consent and\or to discontinue participation in this study at any time.

Confidentiality: The information you provide, such as your name below, will be identifiable to the researcher team only. The members of the research team will maintain strict confidentiality and not share any of your personal information. For the eventual academic publications individual participants will be referred to in deidentified ways such as "female resident 1."

Q2 If you agree to participate in this study as described above, please enter your first and last name here. This will only be used to match surveys to each other and to the specific solar house.

Q3 Since the last survey has anything changed about your living, education, or work situation such as a change in your housemates, academic major, or job(s)?

Q4 Have you learned anything in your classes about house design and the placement or use of smart home products in your house? If so, let us know what class and a brief summary of what you learned.

Q5 On each of the following pages there will be a short description of a device and questions about that device.

Device Questions:

Q6 Please rate each device based on where you think it best fits between each phrase set.

Q7 Please rate each device based on where you think it best fits between each phrase set.

Q8 In which ways would this device be beneficial to you? (Mark all that apply)

Q9 Please add any additional comments you have about this device.

Q10 Thank you for rating those. Now, we would like to ask you a few general questions pertaining to all the devices you have seen in this survey.

Q11 How much do you agree with the following statement: If I had to purchase these smart products on my own, the cost of them would likely be a major obstacle.

Q12 How important are each of these to you in regard to setting up your home? (Mark all that apply)

Q13 What technologies and devices have you added to your solar house since the last survey? Please list if any.

Q14 Since the last survey, have you use any of the following to learn about any of the smart home products in your house? (Mark all that apply)

Q15 Were you satisfied with the information you found?

Q16 Did you enable, disable, or move around any of the smart home products this month? If so, please explain.

Q17 Did you connect any of the smart home products to each other or to other technologies in the last month? If so, please specify which ones and explain what you did and why.

Q18 Did you or others add any new technology to your house or change any of the existing technology? This could be repairs, additions for a specific purpose like a box fan for summer, or just new purchases like an Xbox. Tell us the any additional information about what happened or why it was added.

Q19 What new smart home products or technologies would you like to be added to your house? Why would they be useful?

Q20 Who are the other people who come to your house and how do they use the smart home products if at all (do not mention names, but refer to people by roles such as friends, classmates, relatives, or significant others)?

Q21 Thank you for taking part in this study! If you have feedback or encountered any problems, please let us know here:

APPENDIX B: INTERVIEW QUESTIONS

1. Did you feel that the training you received at the beginning of the semester was sufficient for you to use the devices in your home?
2. If not, what training would you like to have received?
3. How important was it for you to take advantage of the SHT in your house?
4. What features did you utilize most—or wish you had been able to utilize?
5. Did you use any advanced features—such as paring devices to control your thermostat or using a mobile phone app to control the household lights, doorbell, etc.?
6. If you did not use many of the features—why not?
7. How much time did you spend trying to learn to use the technology?
8. What sources of information did you consult? Web sites? Friends and family?
9. How important is SHT to you moving forward in your life?
10. Do you see yourself investing in SHT in the future? Why or why not?

APPENDIX C: SMART HOME PROBLEMS

During the semester, various issues were encountered regarding the technology installed in the various smart homes. These issues ranged from simple items such as users forgetting what they had named a device, to inability to access some software critical to using the full suite of available technology.

The encountered problems included:

- Resident forgetting what they had named a particular item.
  - Issue encountered in 2 homes (2002, 2013)
  - First instance was resolved by re-sending Google shared Drive link with account information
  - Subsequent instance required installer to visit home and conduct remedy directly form user's device (all apps were still on device, and logged in correctly)
- Residents unable to connect to system
  - Issue encountered in 1 home (2015)
  - After initial setup, and successful deployment of technology, users were unable to operate smart home devices
  - Several rounds of troubleshooting concluded issue was with "Wink 2" smart hub device (device allows various technologies to communicate with each other)
  - Problem arose from internet provider changing parameters of service (change of bandwidth, among other attributes)
  - "Wink 2" product was very difficult to perform a "reset" on without changing IP address (troubleshooting guide covered how to move locations, but resetting while keeping original IP address was not covered)
  - Problem was eventually solved by physically moving device to connect with different internet service, then returning to original home
- 3rd party software
  - System installed in a home (2015) does not allow for direct communication between installed control technology and voice supported devices
  - Loxone system does not support voice control

    – Have communicated with factory representatives, they REFUSE to allow any direct control form major automation companies (Alexa, Google Home, Apple Homekit, etc.)
  - They will allow system control through a cloud-based 3rd party application (1 Home)

    – 1 Home application requires paid monthly subscription

    – To use voice activation, user is required to give login information for service being used (In this instance, Amazon Alexa)

    – Issue arose when Amazon account being used by residents was family account with parents. Account had several paid subscriptions and was also linked to a credit card for on-demand purchases

    – Residents did not feel comfortable giving information to 3rd party to utilize voice control
- General software issues
  - Several instances were encountered where various software used updated terms and conditions, or other such cases.

    – These required resetting accounts, and occasionally reconnecting inter communication access
  - One instance involved Lutron system in which an expired security certificate within the code caused sever disruption between voice activated control, and the app for lighting control

    – Troubleshooting eventually resolved this issue, after inquiring on Lutron Forum

    – Resolution involved fully deleting both applications from user device, then re-installing application in a particular order while performing cache clearing

    • While investigating this problem, various software used in home automation use the types of security certificates, and many are known to cause significant disruption in the near future without much notice

APPENDIX D: (CLICK FOR FULL DOCUMENT)