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Where is the interface? – Appropriating Interaction with IoT in the Smart Home

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Abstract

With the proliferation of IoT the home is becoming a "smart" space that provides new opportunities for supporting creative experiences for the user. Adaptable IoT devices offer the possibility for users to appropriate interaction in the home. The objective of this paper is to explore the use of a configurable, placeable, IoT enabled button as a way for users to appropriate interaction with the smart home. The study employs the methods of technology probes, photography, and contextual interviews. Our findings show that our users configured the IoT enabled button to manage automation in the home, to install place-significant shortcuts for relevant smart home features, and to create interaction points for tasks that support the user's daily routines. We propose that IoT should not only be seen as a way to increase efficiency in the home but also as a vehicle for user-created interaction opportunities that can creatively support rising needs in each user's daily life.

Keywords: IoT, Interaction Design, Smart Home, Tangibility, Smart buttons, Appropriation.

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1. Introduction

The popularization of IoT (Internet-of-Things) has enabled the production of novel products and services and has raised the expectations for seamless human-to-object and human-to-system interaction. IoT systems enable diverse modes of interaction that highly influence the degree of usability and richness of user experience in their application contexts. While IoT can augment and enrich both professional practices and everyday life, it is, at the same time, reshaping the domains of use and the modern home is one such domain. IoT facilitates the shift from "home" to "smart home" where new possibilities for living and managing the home space arise. This facilitation poses some challenges in terms of how interaction with IoT *must* align to rhythms of everyday life that are unfolded in situated ways and are hard to foresee for designers and developers.

In this paper we wish to focus on the entanglements of everyday complexity with an ecology of devices in the case of a smart home security system. By leading a design intervention with the security system through placeable, configurable IoT buttons, our aim is to investigate if and how users appropriate the buttons into the smart security system to creatively manage interaction with their smart homes. By acknowledging the potential of IoT for fulfilling the diverse and unpredictable needs that arise in the modern home we wish to uncover implications for how to design for future technology in domestic environments using IoT technology. Further, we present a plausible methodological stance for exploring user's needs and desires in the smart home over a period of time. The exploration is a tech probes study [1] which took place in the actual homes of several families who were already users of the smart security system. The study focused on issues of interaction, appropriation, and configuration of the buttons in existing smart home systems.

Even though pervasive computing is moving beyond the personal devices to everyday 'things' with the help of

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embedded technology, smartphones with dedicated applications are the most common way used for accessing data resources and services that facilitate smart living. Often this is complemented with web services providing interfaces for accessing and managing the full functionality of smart home services and applications. In parallel, a plethora of alternative interaction models have emerged that go beyond the traditional screen-based user interfaces, and relevant research questions arise in relation to how we should design for enabling interaction with the smart home in all its complexity. Issues of interaction with smart living systems and services have been of recent academic interest [33] and we find that such research complements contributions from more technically oriented research disciplines such as computer science and information systems.

The smart home can be described in terms of how people are enriching the home with intelligence through a continuous coupling of things in the material world with everyday routines in specific social and technological arrangements. Smart lights, connected home security systems, smart thermostats and voice assistants are instances of IoT technology coupled with daily home routines such as waking up and getting ready for work. Since our lives are unique to each of us, the couplings of IoT and daily routines are performed in a variety of diverse ways The heterogeneous needs that take place in the home can be difficult to accommodate with pre-configured systems. Therefore, fulfilling such needs requires further research and exploration.

Relevant research questions arise in relation to how we should design for enabling interaction with the smart home in all its complexity. Knowledge on when and where users need to interact with the smart home and how users can cope with managing an ecology of diverse devices and services, each with potentially different interfaces and varying capacities, becomes increasingly needed. Interaction points become crucial in using a rich ecology of devices - not only for controlling devices but also for automating their functions, thus adding a new layer of technological complexity to existing devices. Along with setting up automated behaviors people manage their homes by making explicit use of old and new interaction points such as toggle switches, smartphones, tablets, gesture-based interaction and voice-control. In this paper, we wish to focus on the entanglements of everyday complexity with an ecology of devices by exploring how people manage interaction with their smart homes.

There has been a recent surge of market-ready devices offering user-configurable tangible controls that integrate into an existing ecology of devices and services in the home. The Logitech POP button [2], the Flic button [3], and the Bttn [4] are examples of such devices that serve as direct interaction touch points for carrying out an array of functions at a button's press – from toggling all lights in a room, to calling a taxi or ordering a pizza. As these buttons are easily configurable, they have become popular choices for integration in the smart home. In spite of a vast amount of research on the home [33] we find that there is little research about adopting market-ready configurable devices into homes that are already pre-installed with smart home systems. We speculate that the configurable and placeable qualities of these buttons, complementing other control interfaces, could potentially enrich the entanglements between people and their interaction in domestic settings and lend insights about potential implications of using these buttons to interact with the home.

1.1 Aim

Our aim is to investigate if and how users appropriate a smart home security system through placeable, configurable buttons in their smart homes. By acknowledging the potential of IoT for fulfilling the diverse and unpredictable needs that arise in the modern home we wish to uncover implications for how to design for future technology in domestic environments using IoT buttons.

In the following sections we identify issues related to automation leading to inflexibility and fewer interaction possibilities, and the importance of a blend between "smart" technology and "traditional" smartness. We then present findings organized in the themes of place-specific control and tangibility, habit-making and automation management. Finally, we discuss these findings in relation to relevant work and carve out opportunities and challenges of using adaptable, placeable and tangible devices as a way to increase the diversity of possible interaction in the home.

2. Background

The field of domestic computing and the visions of the smart home being explored in numerous research projects in past decades share a significant heritage from the time of Ubiquitous and Pervasive computing [for example 5,6,7,8]. This heritage includes strong design ideals in relation to interface design and how we can develop capacities for users to interact with technology in complex domestic spaces. One such design ideal is the very notion of seamless interaction itself. But this notion has also been contested by several researchers, which has led to alternate interpretations of "seamlessness" where technology ought to empower users to make decisions for themselves rather than have decisions made for them. One such alternative was put forth by Chalmers and Galani who proposed the concept of "seamful interweaving", [7] where the human capacity for fragmented information handling is not only a potential but a fact; "*Activity continually combines and cuts across different media, building up the temporal patterns of coupling and interweaving that constitute experience and understanding*." [ibid]

In that, the authors argue that a system with visible seams affords more interaction and appropriation opportunities to its users than a completely seamless solution. The characteristic of seamlessness in technologies makes them monolithic and inflexible to the extent that it becomes virtually impossible to adapt these technologies to anything other than preconfigured actions. This is one of potential shortcomings in using current, preconfigured, seamless IoT systems. Some of the strengths of IoT systems are the capacities for context-aware learning and sticking to scheduled automatic behavior (e.g. lights that turn on automatically at sunset). But in situations where unexpected phenomena in domestic life render the automation obsolete, complicated or time-consuming existing modes of interaction for re-configuring automation create lower trust in the system among users. A study conducted on the usage of the nest thermostat system by Yang and Newman [8] highlights that users do not always trust the intelligence and automatic learning capacities in the system. Further, the authors propose interaction strategies for future development of domestic technologies such as the strategy of "exception flagging" where users are able to prevent smart home systems from learning certain user behaviors that may be unique to particular circumstances, and "constrained engagement" where the system is designed for short, informative interactions given that users are unwilling to engage with thermostat setups for extended interactions (ibid).

2.1 IoT in the home

Often the use of "smart" refers to an interpretation of autonomous system behavior where decisions are taken on behalf of users and where explicit user interaction plays a lesser role. In relation to the smart home, Taylor et al. claim that homes have always been smart in the sense that the people inhabiting them continuously configure and connect mundane home artifacts such as fridge doors, notice boards, walls and furniture etc. [10]. Following this line of thought, IoT based technologies do not make for a radical departure from traditional home settings. An example of how one can consider the use of "analog" household components is that of Harper and Shatwell, who analyze how different things such as a paper note put on the table is used as a "situated display" and how placing these displays around the house might constitute "ecologically distributed networks" [11]. It does not seem far-fetched to mix traditional and technological "smartness" in the home and several studies have observed how households configure domestic technological appliances by themselves (for instance [12,13,6,14]). One relevant study of home technology appropriation through IoT is that of Vianello et al. [15] where the authors developed a tangible system for supporting users' needs in the domestic environment. The study utilized one family as their users in a day-long workshop setting. Findings indicated that the family came up with many different scenarios for using the technology that was given to them, pointing towards the promising nature of configurable, placeable interaction points for home use.

In this study we extend previous such findings by focusing on how people configure their own homes by entangling IoT technologies with various physical spaces of the home in order to meet the unique needs of the household.

2.2 Appropriation

Despite the rather high degree of maturity that contemporary domestic technologies have achieved we can still observe a reluctance among consumers to adapt to these technologies. This is at least partially due to the fact that the user perspective of the home rests upon a large longitudinal temporal frame, where appropriation of technologies appears gradually and slowly. It is a process that is hard to observe in singular moments and in settings outside of the actual home. In a series of interviews, Brush et al. address the long-term experience and conclude that there are barriers in the form of high cost of ownership, inflexibility, poor manageability, and difficulty achieving security that must be overcome for a broader adoption of smart home technology to take place [16]. Paul Dourish, in a seminal book, highlights the significance of appropriation in the adoption of technology, where appropriation is described as; "(the) need to be able to customize the space to our changing needs; we need to be able to appropriate it to the purposes at hand.... we also need the ability to turn and twist the setting to suit our immediate purposes, which in turn requires that the environment be malleable enough to support this sort of appropriation" [17]. Appropriation has been an important, beneficial process that has been studied in relation to understanding user interaction with technology over. time and to further understanding of technology use in a domestic space [19].

One way of promoting appropriation is to engage users in configuring home technologies; this means engaging users in learning about pervasive computing technologies by appropriating them in individual or collective ways, and thus building up trust towards automation. While the process of configuration is more demanding than having a completely pre-configured automated system installed, completely automated systems face challenges of inflexibility and at times manageability mentioned above [9]. There are several solutions for end-user configuration that do not demand previous expert technical knowledge. Examples range from visual metaphors to "trigger-action" schemes and using do-it-yourself (DIY) technologies. Further, commercially available online platforms like IFTTT (If This Then That, [20]) and Zapier [21] offer plug and play solutions for end-user configuration of IoT services and devices without demanding any prior programming skills.

3. Study design

In order to explore smart home appropriation through IoT, we designed a study based on the technology probes method [1], contextual interviews [34], and photography. The contextual setting for the study was the use of a commercially available smart home safety system provided by a major company in home safety and security. We are unable to name the smart security system due to confidentiality agreements. For similar reasons, images of the system have been carefully modified to provide a close approximation to the real system (figure 1). The system includes a numeric keypad module as a standard feature, and an assortment of connected devices such as cameras, sirens, motion sensors, key fobs, smoke and humidity detectors that vary depending on each household's configuration.

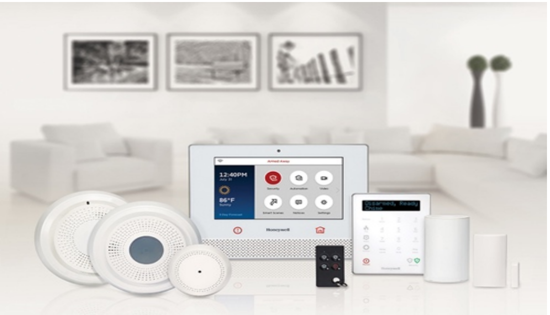

Figure 1. An ecology of devices in the smart security system.
(https://avteck.ca/product_images/uploaded_images/01-lyric-homeinside-devices.jpg)

As shown in image above, the system offers several interaction venues such as a smartphone app, RFID key fobs, a web interface, a physical control panel and the possibility for users to automate system behavior based on temporal and environmental triggers such as available natural light and time of day. The variety of features and different physical units highlights how domestic IoT can be described in terms of ecologies and how diversity in use becomes a challenge. As a design intervention, we added a multi-purpose, configurable bluetooth button to control the smart home. This market-ready button was modified to integrate with the smart home security system.

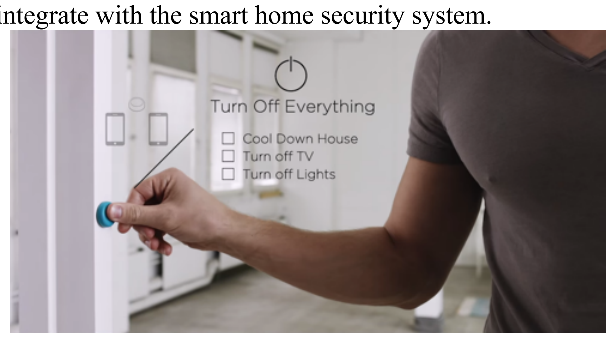

Figure 2. Wireless Bluetooth button for the smart home.
(http://assets.coolhunting.com/coolhunting/mt_asset_cache/2014/11/cute-as-a-button-1.png)

The wireless Bluetooth button comes pre-configured with three modes of use: single press, double press, and long press. It is about a coin's size, made of silicone material, and it has a sticky surface on the back to mount on flat surfaces.
As the button's configuration is fairly straightforward, it was possible for the smart home users to assign what functionality should the different button states trigger. However, no visual or other feedback was provided by the button. This was compensated by the security system's smartphone app that gives an overview of the system's status. Additionally, it was possible to configure system events that react to the button's triggers through the smartphone app. We will refer to these trigger-based user-programmed events as recipes.

For the sake of consistency in the study setup, we verified that all participant families installed at least two smart plugs connected to the security system, the reasoning being that a smart plug allows the user to adapt home appliances with automation based on recipes. Finally, the security system offered further possibilities to secure the home with door locks, cameras, and other types of sensors.

Several research initiatives such as Home Aware [22], the Adaptive Home [23], and the Home of the Future [24] have addressed the need of studying domestic computing in context and over time. Still, dedicated research houses take on the role of a kind of lab that is hard to compare to actual homes. Further, the focus has often been on new, or even futuristic, technologies and scenarios. It is highlighted by Mennicken et al. how "...such technologies therefore cannot be studied in the wild, because "the wild" simply does not reflect those scenarios yet." [25]. Here we study technologies that are new, yet already in use "in the wild", the wild being the participant families' own homes.

3.1 Participants

Since we were interested in studying appropriation with a relatively new technology, we selected participants that consider themselves experienced technology users. Using a survey, we recruited 5 families that have owned the smart home security system for at least 6 months prior to the study, own modern smartphones, and rate themselves highly when asked about their perceived technological fluency, as shown in table 1. Families were dual income families that live in detached or semi-detached housing. Four of the five families consisted of two adults and between 1-3 children, and one family consisted of two adults. All of the families had home automation schemes in place before we initiated the study. The home automation was in the form of smart plugs that turn lights on and off based on a time schedule that the families had configured themselves.

Table 1. Self-reported technological fluency of participant families.

Technological Fluency Statement	Mean Score	Median Score
I consider myself knowledgeable when it comes to new technology	4.2	4
I consider myself an early adopter of new technology.	3.8	3.5
I am comfortable with configuring smart home devices	4.6	4.5

4. Method

There are two main methods that were used in this study; the first method is an adaptation of the technology probe method by Hutchinson et al. [1], and the second method is the semi-structured, contextual interview.

Technology probes is a user research method that employs an open-ended technological solution for the purpose of collecting user data while also enabling active user participation in the design process. Hutchinson et al. [1] present technology probes as a method that can help determine what kinds of technologies would be interesting to pursue. Some important relevant characteristics of a tech probe study is that the study takes place over a period of time significantly longer than a typical lab study, and that the study takes place in context which in this case was the participants' homes. User diaries are utilized as an over time data collection method during the probe study [1]. Previous literature has identified the importance of context and time on the user experience of a technological artifact [26,18]. The longitudinal and place specific natures of the study enable us to study technology appropriation as part of the user experience that unfolds over time and in context.

In our study, we used technology probes as a way of allowing users to appropriate technology by adapting, placing and configuring tangible interactions in their homes. Study participants were given a probe kit that contained three buttons, a button hub, and a study pdf with instructions and an initial task for each family. Participant families were instructed to use the probes as they see fit for 6 weeks and report on their experiences on a weekly basis via an experience diary format, where each family was asked to submit at least one diary entry per week. Email prompts reminding participant families to fill in diary entries were sent once a week. Each email prompt contained questions regarding positive and negative experiences with the buttons. We further prompted participants with a unique question addressing specifics of interaction with the buttons each week.

After the six-week study was over, the diary data was analyzed using open coding [27] and used to formulate semi-structured interview questions with the study participants. The interviews were used as an opportunity to deep dive into often short diary entries and to ask follow-up questions and collect the participants' retrospective experiences with the technology probes. Each interview lasted about 60 minutes. The interviews were recorded, transcribed, analyzed using open and axial coding [27] and condensed into the findings that we present in the following section.

5. Findings

Based on our interviews and diary data from five households, we learned that our participants configured automated behaviors of the smart home and had positive experiences with automation in their homes. In most cases, our participants used the buttons in order to gain back control through intervening in automation as and when required. In this section, we focus our attention on specific aspects of appropriation and configuration of the smart buttons that detail where the buttons were placed, what tasks were assigned to them, and how the participants interacted with their smart home through the tasks assigned to the buttons. We also address specific findings related to qualities of the buttons.

5.1 Smart buttons for place-specific control of smart home functionality

Our participants were quick to put the smart buttons into use by configuring them with tasks and placing them at convenient locations in their homes. The freedom to place buttons where needed was very important for our participants.

The most common use for the smart buttons was controlling connected lamps in the home by placing the buttons in common areas such as the living room and the kitchen. This type of configuration might seem trivial in relation to the high-end technological expectations for the smart home, but it illustrates how situated interaction is dependent on the home as a place constructed of sub-spaces being in continuous interaction with everyday routines. We quote below from an interview when a participant was asked to describe the placement of the button:

"...In a central area in the kitchen... when we are on the first floor, the kitchen is the most commonly used place, so if you want to turn on the lights for example, that's normally where you'd end up."

Many participants appropriated the smart buttons so that they became a part of their day-to-day routine such as turning off all lamps at one go from the same place.

"The recipe is - when clicked [once] two smart-plug connected lamps are turned on and when long pressed the lamps are turned off. Hence all the lights in the living room can be operated from the same place."

Often the smart buttons occupied a traditional place in the home alongside frequently accessed areas such as switchboards, key tables, phone charging desks, or even alongside traditional light switches as shown in figure 3.

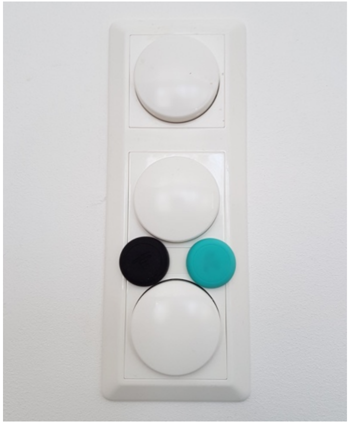

Figure 3. Buttons placed next to traditional switches in a participant's home.

"I had all the buttons together [...] The green [button] turns off/on lights. I put it next to my keypad to be able to do it when I leave/come home outside of my pre-set hours for the lights on/off in smart-scheduling."

At the same time, not all our participants assigned traditional places to the buttons. For instance, one participant placed the smart button on top of a thermostat conveniently situated on the way to the bedroom (figure 2), while another placed a button on a table next to the sofa for getting access to a lamp that was not in her reach easily.

"either you bent over the sofa to find the smart plug or you pick up the phone and use the app... it takes some time to do that so that's a good use case where the buttons solved this problem because you sit on the sofa and it's like 10:30 and the lights get turned off but you actually want to turn them on which is quite easy with the buttons."

Placing the button on the table was a matter of reducing the time and effort it took to control the lamp from the smartphone or to bend over the sofa to find the smart plug. On the other hand, it was evident that the button extended the possibility of completing the same task from multiple sites in the home.

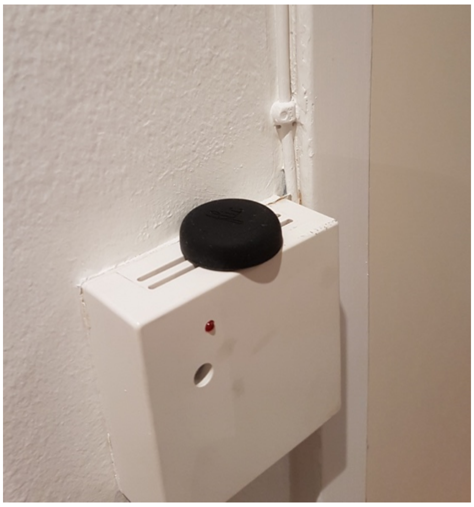

Figure 4. A Button placed on a thermostat on the way to the bedroom.

Another participant configured three buttons to perform the exact same tasks by placing them at different locations in the home, namely the kitchen, the master bedroom and the children's bedroom. This brings up an interesting insight for interaction where the buttons offer a tangible handle to control automation from multiple sites that can also be accessed by cohabitants without requiring the smartphone app. To that extent, many participants were averse to the idea of controlling connected objects using just the smartphone. Even though on-screen interaction offers vastly more possibilities than a single button, the smart buttons compensated to some degree by providing immediacy, configurability and accessibility in a placeable format. While commenting on the physicality of the buttons, one of the participants even claimed that:

"physical interfaces requiring touch is the most efficient way of interacting with machines."

Placement was sometimes used in unexpected ways. One participant placed a button near a laundry room door handle. The button triggered a dehumidifier in the room, and the placement was used as a physical reminder to turn the dehumidifier on when doing laundry in order to avoid mold.

5.2 Smart buttons for supporting user routines

We have seen that IoT devices offer multiple points of interaction in the home for completing the same tasks, with placement being a valued aspect of the button. Another point of interest was the assignment of tasks that matched our participants' routines and habits to the buttons. With the open-ended configurable design of the button, our participants saw new possibilities for interacting with connected objects in their homes. The buttons consisted of three states namely short press, double press and long press, where each state could be configured to perform a specific task. The most common usage of two of the three states was toggling a function, such as turning a lamp off with a short press and back on with a double press. Many participants in our study had assigned similar toggle controls to the buttons. For instance, one study participant assigned one button to turn off/on a smart plug connected coffee machine, the second button was used to turn off/on a connected lamp, and the third was also a light switch but it was used to control Christmas lights. While these controls had little to do with automation, they point at the possibility of distributing tasks between different buttons and its states.

In another family, one of the participants configured a button by placing it on the way to the bedroom and assigning a short press to turn the lights out, a double press to arm the home security system, and a long press to run both the tasks at the same time. This configuration allowed the participant to automate her bedtime routine while still being in control of each nested task in that operation. In a similar fashion, another participant discussed how the smart button offered distributed control of tasks in automation.

"The difference is that the night control always puts the alarm in armed home state (night mode). The new button lets us make sure that the smart locks are closed, and the lights are out without arming the system."

5.3 Smart buttons for managing automation

Previous work has shown that automation cannot always fit rising needs, since these needs can be a moving target [8]. In our work, smart buttons were used, among other things, as a way to overcome automated system behavior, to shape it into what is needed in the moment. Unanticipated situations requiring momentary intervention, like the occurrence of bad weather, as quoted below, is a common issue when automation is set to a fixed schedule.

"[...] Since I have all my lamps on automatic, I don't turn them on and off. For example, when it's very dark outside because of a lot of clouds, I have turned it on, especially during winter time."

In most instances, our participants seemed happier to not change or undo automated schedules because they want to avoid the trouble of re-configuring the system's automation settings. The smart buttons solved this problem by overriding automation whenever an exception was necessary. For example, if all the lights automatically turned off at 10PM during a late-night dinner party, smart buttons could be used to turn them back on without having to reconfigure the system, thus illustrating the need for overriding pre-set scheduled automated actions at times. Another scenario relates to the arming and disarming of the system. The quote below illustrates that the buttons were not only used for deliberately overriding schedules but also in situations when participants were uncertain of the current system status and how the different functionalities affect each other.

"...if I arm the system we will end up with false alarms for example when you go out in the morning and forget that the alarm is armed when you let the cat out.... that's quite annoying so it's good to know that everything is turned off without arming the system."

5.4 Habit-making, physicality and feedback

As the buttons became part of the smart home, different behaviors emerged and a pattern of button-use (or non-use) solidified. When asked whether button use has become a habit for them, three of the five households were affirmative:

"[...] I think that (the button) was very good to have even from day one. [...] we use it every day."

We find that habitual use of the buttons is heavily dependent on placement and the utility that the buttons possess for the users. Since the buttons are user-configurable and user-placeable, the users increased the possibilities of habitual use of each button, given that the users could foresee their needs and that a physical button shortcut affords the possibility to satisfy these needs.

Yet another user stated that button use became a habit quite quickly for him but not for his spouse. One main difference between them is that the initial user engaged in configuring and placing buttons, thus establishing a sense of ownership, whereas the spouse had minimal interest, and thus involvement in the setup process. We believe that involvement in the setup process may be a key point for engagement and appropriation to take place.

Certain aspects of interaction are seen as important by the participants. Feedback is one such aspect where participants commented on lack of feedback from the button:

"This button is good as the input thing but it's bad for the feedback."

"But the thing about the button is that the feedback is poor"

Since the buttons afford interaction with the system without offering direct feedback, our users relied on other interaction points for receiving feedback that their button presses were effective. One common way of receiving feedback was by observing actual events in the world. One user felt assured by hearing the physical lock click rather than the screen-based status confirmation. He also placed the button in the vicinity of the lock, so he always had the possibility to actually hear the lock being activated. Similarly, some participants relied on noticing feedback from the device(s) that the button operated when possible. For instance, if the button was configured to turn on a set of lights, and the lights are in the participant's' line of sight, then that would be considered as feedback. In cases where feedback was not perceivable, participants checked the system status on another interaction point, often the smartphone app that is available as a standard feature of the smart security system. These findings highlight that in an IoT system there is a potential to design for using one device for system input, and another device for providing feedback when necessary. Taking this a step further, it may be worth exploring ways that users can further appropriate their smart homes by configuring interaction and feedback points that work best for their homes.

Further, our participants went to the extent of reflecting on other modes of interaction including voice-control and touch-displays in comparison to the button.

"I think the button is much better than voice-control because it's faster and it's easier, and it's quiet."

"Touch screens can be very good for feedback, but not always very good for different kinds of input. So, it depends… And big touch displays, I don't think those are optimal for all situations either."

In that, some participants commented on tangible aspects of the button. Comments ranged from one participant stating that the button "Feels nice to push" and really liking having a physical button to one user commenting on a button that had "almost no click-feeling" even though the button did function. Clicking sensation seems to be an important aspect of the physical nature of the button, and something that separates the button from digital interface touch points where interaction offers a different kind of experience altogether.

6. Discussion

Our study findings indicate a strong user interest for providing possibilities for users to make their own IoT configurations as immediate needs occur in their everyday life. Previous findings in a day long workshop setting indicated that configurable IoT devices may be promising for adapting smart home functionality [15]. This study contributes by extending previous results to show that the needs of daily life can be fulfilled by user configurable IoT devices. These emerging needs are hard to foresee, even by the users themselves, in the moments where automated schedules are set up. Such needs are characteristic of the intimate setting of the home in terms of how living takes on unanticipated turns in concert with slight changes in everyday routines, extraordinary events and even the temporality of the changing of the seasons that change light conditions. Even though the smart home security system offered several distinct arrangements for interaction with the home (smartphone, keypad, voice-box), the possibility to easily configure the buttons for performing certain actions at multiple points was an opportunity welcomed by our users. Interestingly, all the study participants voluntarily chose to keep the button setups after the study was finished.

As an implication for HCI and interaction design we conclude that despite the obvious advantages of centralized overview and control in a visual interface, it is fruitful to understand the smart home as an ecology of different interaction opportunities. These opportunities to interact may demand different qualities and characteristics that can be unforeseen by experts and users alike before life happens. Therefore, leaving some room for end-user configuration and customization provides flexibility that is desirable by our users. Another benefit of the buttons was the possibility to override automated system actions such as pre-scheduled light control. With automation being dependent on situated moments and ever-changing conditions, designers are responsible for providing means for easily overriding the automation when needed. These findings are in line with previous work that highlights the importance of designing interaction opportunities with automation in the home [28], and research that presents collaboration as an important aspect of interaction between users and automatic home systems [29].

One much appreciated opportunity was the simple act of easily placing the buttons anywhere our users desired. Often the aspect of designing for mobility and changing places are thought of as being able to have access to functionality anywhere and at any time. Our study findings show that there is a need for making interaction place-specific, having it accessible in the places where it matters most. The ease of use in a quick button press compensates for not having "everything at hand". Other instances of place-specificity related to being able to place the button within a specific path of movements, such as "on your way to the kitchen from the bedroom".

The fragmentation of devices also creates some challenges. While the buttons are easy to use and cheap, bordering on being disposable, they clearly had problems in terms of feedback. The possibility for placing the buttons near the origins of sound or light could compensate to some extent in terms of how you could see or hear the effects of action. But still, most users found the lack of feedback in the use of the buttons troubling. This implies that feedback is a valuable aspect of domestic computing and should be addressed in the introduction of extra devices as the buttons. Recent previous work by Liu at al. [30] has identified feedback as important in interaction with IoT systems in general as well.

The findings presented in this paper indicate the need for further work in order to obtain a more rounded understanding of how families use and appropriate interaction with their homes through adaptable IoT technologies. Besides studies with larger sample sizes and longer durations, we believe that it would be beneficial to also study other modalities of interaction in the smart home, especially concerning how can users appropriate smart home interaction through voice or gestures, or other physical interaction. Interaction with automation in the home is another venue that should be explored further. There is much published work on how automation can work from a technical standpoint, but there is also need for work on where, how and why automation could be used as part of a home ecology.

7. Conclusion

IoT technology is rapidly changing our lives, and the home is no exception to this change. Given the growth of smart home systems and the unique nature of the home as our most private space, we set out to explore user appropriation of smart home interactions through IoT enabled buttons in a smart home security system. Our findings show that our participant families welcomed the opportunity to make smart home systems their own. Our users leveraged configurability, placement and the physical nature of the buttons to create custom interaction points that helped them manage automation, create convenient shortcuts and fulfill the emerging needs of daily life. These findings contribute to the field of domestic computing by illustrating that supporting appropriation of interaction with smart home technology through user-configurable interaction points is an important element for the success of IoT systems in the home.

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