Coping with Changing Temperatures: Interactions of People Facing Cancer and Menopause with Home Energy Management Systems

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Home energy management systems (HEMS) have changed over the years, particularly with the development of smart home technologies which aim to simplify people's lives. As life can be hectic, people look to technology to assist in streamlining daily activities, including setting home temperature. The dynamic nature of household composition, including changing residents, guests, as well as changing health status, necessitates the continued evolution of home heating and cooling systems. This research seeks to delineate design considerations for building a home energy management that can interact with situational variants and assist in temperature decision making, relieving users of added stressors during times of familial changes. This research discusses home energy perceptions of people facing either a diagnosis of cancer or experiencing menopausal symptoms in order to discover opportunities for a novel and perceptive home energy management system that considers household structure and familial dynamics.

Guides; instructions; design kit; Energy; HCI; Context; Design; Consumption; decision support

1. INTRODUCTION

When determining home climate settings, all members of the household have different contexts within which they determine optimal temperature. Considering other people's thoughts and feelings significantly changes the dynamic and adds to the difficulty. Examples of contexts include where people are located in the house and if they are sedentary or active. In addition, a health event like a diagnosis of cancer or the onset of menopause increases the desire to improve individual comfort levels, which compounds the situation. These dynamics result in family members working to compromise on individual comfort, the comfort of pets, the health of plants, a desire to save money, and environmental concerns. These factors impact the decision-making process in setting home temperature [9, 10, 16, 19, 26].

This work describes how people facing a major health event that alters their sense of ambient temperature (such as cancer or menopause) interact with home energy management systems. This population is unique because their health event impacts their perception of temperature, adds to the overall stress levels of the family [21], and complicates the ability to set a home temperature that is comfortable for all household members [16].

Home temperature decision making is a compromise between household members and their individual comfort needs. In studying a population dealing with a health event, we seek to understand how technology can assist in setting home temperature while also determining if one stressor can be removed by using a perceptive system.

Through interviews and surveys, this research endeavors to discover design aspects for a novel, perceptive interface for interaction with home energy, in particular the home's HVAC (heating, ventilation, and air conditioning) system. In order to assist decision making between household members, reduce stress and improve home comfort, this interface strives to inform temperature choice in consideration of the varying nature of household dynamics, particularly when one occupant is faced with a significant health event.

2. RELATED WORK

Individuals often choose the path of least resistance when making home energy decisions [8, 19], often leaving their thermostats at the same temperature whether people are home or away, not using available programming features of a thermostat or not changing programming when life, seasons or family dynamics change [12, 16, 22].

There is a large body of research in the smart home and sensor community that focuses on augmenting energy consumption or smart meter data with contextual data [11, 19]. Contextual data, such as how many occupants are in the home, what activities they are pursuing during their time in the home, and current weather, can help in improving predictive

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models of thermostat usage and building better demand-response systems. Collecting this data often requires deploying sensors to monitor occupation, temperature, motion, and light [23, 24] and inferring actual familial activities such as cooking, watching TV, or other general work [5].

In the sensor community, the approach taken is to first collect data from varied sensor modalities, and post-priori analyze the data to find ties between energy usage and the underlying context. This is a valid approach but often interferes with regular domestic activity by "cluttering" the home environment. In addition, this information doesn't augment the decision-making process without a proper understanding of the factors that affect home energy choices. This is because there are several factors such as social structure, family hierarchy, individual comfort, and health status [9, 15, 23, 27] in addition to known factors like household activity and occupancy that affect home energy consumption.

Our study adds to current research by focusing on a specific population to understand their considerations and interactions with their current home energy management systems (HEMS) in order to inform a design for all home occupants, their current health status and well-being, and individual comfort.

To gain a deeper understanding of the problem and corresponding factors, our approach was to survey and interview homeowners and renters to first explore the underlying causes and complications of temperature choices in the home in order to discern insights and preferences for building and testing a perceptive user-driven home energy management

2.1 Contextual Household Dynamics

Commercial thermostats have changed from dials to programmable to "learning" (Figure 1). The idea behind a "learning" thermostat is that it learns about a person's habits within the home and adjusts the temperature based on when the person is at home or away [33]. In addition, many cities across the country have implemented smart meter technology. For clarity, a smart meter is an advanced electrical meter that monitors electricity consumption. It is able to transmit information about energy consumption from a building or home back to a local utility for monitoring and billing purposes [29]. This technology can monitor electric consumption and provide granular data on home appliance and system usage in order to inform a system that can assist in decision-making for optimal home temperature for all occupants.

A B C

Figure 1. *Number dial turn (A) programmable (B) "smart" (C) thermostat interfaces*

(A, B © Honeywell, C © Nest Labs)

The fact that pets and plants and other non-human occupants [16] play a big part in their energy decisions is not considered in current HEM system design. For example, no system takes into account that the family pet is still at home when others are out or how much energy is used to keep a citrus plant alive during the winter months. If a system is to learn occupant habits, then these factors must be considered to provide effective guidance for decision making.

This prior research indicates the need for perceptive and feedback-based energy management systems. Daily habits are often repeated because they occur without conscious thinking [8], therefore it is important that the system be able to take into account both habits and significant, temporary and long term events that change these habits.

3. HEALTH EVENTS AND HOME ENERGY

Considering these factors, we wanted to take a closer look at changes that occur within families and how these changes affect home energy choices, specifically when a family is faced with a significant health event that impacts home routines and decision making within that framework. In particular, we chose to focus two different groups facing a health event that alters their perception of ambient temperature: people who are experiencing menopausal symptoms people who have been diagnosed with cancer and are undergoing chemotherapy or other drug treatments.

A health event is a time, either short of long-term, in a person's life when they are experiencing symptoms that relate to a change in health status. When a person has a cold or the flu, for instance, he or she often feels colder and perhaps chooses to use an extra blanket or put on fluffy socks. This health status is often temporary so making a change to thermostat programming might be overlooked. However, when a more permanent health event happens, it would be beneficial to change the thermostat's programming to address the issue.

These two health events were chosen for several reasons. Menopause is faced by most women in their lifetimes. This means that at some point it is likely that a family will have to learn to adjust to dealing with these symptoms. Cancer, on the other hand, can be diagnosed in both males and females and usually has a shorter time frame. With these differences, the research can show whether a perceptive HEMS can benefit disparate familial situations.

Chemotherapy has varying side effects [27] that include changing perception of hot and cold temperatures. Similarly, menopausal side effects such as chills and hot flashes change an individual's desire to control home temperature settings. Thus, the impact on household dynamics regarding home energy could be significant. Studying households with at least one member experiencing symptoms from these events can assist in building a system that not only is aware when and how many people are in the house, but when contextual factors warrant a change in home temperature. Since such a system does not currently exist, discovering new design considerations with this research informs building a perceptive home energy management system (HEMS) interface that will assist in everyday decision making, thus removing the stress of constant compromise which compounds dealing with the stress of the individual health event [27].

This research focuses on discovering how people and their families who are facing such a health event interact with their current HEMS in order to determine if creating a perceptive home energy system would relieve some of the decision-making stressors involved and improve their daily lives. The stress of living with cancer impacts familial relationships, including coping with the changing roles of caregivers and patients and communication dynamics [17]. Such a different type of HEMS could assist in everyday decision making and compromise, thus removing one aspect of health-related anxiety within the household.

4. STUDY METHODOLOGY

To understand how health events such as chemotherapy and menopause impact home energy decision making, we decided to conduct remote interviews and deploy online surveys to households across the United States to determine whether their specific health event impacted their home temperature choices.

Initially, we sent out emails to various healthcare and 'Meetup' groups within a medium-sized metropolitan area. We also put up flyers in different areas of Baltimore in order to recruit participants interested in the study. Baltimore is essentially made up of a series of neighborhoods, each of which have their own "personality". Residents in each neighborhood usually have similar demographics and the homes are similarly constructed. Home types include brownstones, apartment buildings and single family homes.

Limiting the geographical area constrained the number of participants, however, so we broadened the recruitment to the entire United States. We used Craigslist, Twitter, contacted health event support groups via their Web or Facebook pages, and used word-of-mouth tactics to discover people who were going through these two types of health events.

All participants could choose between being interviewed remotely or to respond to the online survey. Interview participants interacted with a researcher for approximately an hour and were compensated $10. Survey participants were voluntarily able to enter a drawing for a $50 Amazon gift card where one participant was randomly chosen for the reward.

We designed both the online surveys and the interviews to include demographic questions, questions about their home's construction, their thoughts on energy usage and what types of home energy monitoring with which they might be willing to participate.

4.1 Interview Questionnaire

For both cancer and menopause participants, we asked questions relating to demographics to get more specific information about their home construction, residents in the home, age, work schedules, and general familiarity with technology. To find out more about their thoughts on energy consumption, we inquired about energy usage, what types of appliances were in the home and how they were generally used.

The interview script had 20 questions and was semi-structured [12]. Using a semi-structured interviewing process enabled the participants to describe in their own words their experiences with interacting with their HEMS, how other people in the home influenced decision making, and other factors that impact their energy choices and consumption.

Follow-on questions inquired as to their methods of dealing with these physical symptoms within their homes, how they currently interact with their home heating and cooling system, and their impressions of current and emerging "smart" home technologies.

- "Do you think that the people residing in your home influence your energy consumption? If so, in what way?"
- "If you have noticed a difference in how you sense hot and/or cold, what have you done within your house to adjust to these differences?"
- "Regarding home temperature has the interaction between members of your household changed since you started treatment? If so, can

you describe how it has change and what the interaction looks like now."

- "If you could choose a method of interacting with your heating/cooling system, which would you choose and why? If you could change how you interact with it, what changes would you make?"

Specific to their health event, questions were asked regarding how menopause or cancer treatment impacted their sense of ambient temperature and if/how it changed their interactions with other family members as well as the home energy management systems.

For participants receiving chemotherapy (chemo), the following specific questions were asked:

- "Can you tell me about how your treatment affects you in terms of temperature comfort? Have you noticed changes in how you sense hot and cold?"
- "Can you tell me a bit about your chemo treatment? When did the treatments start? How often do you receive them?"
- "Have you noticed changes in your energy usage since starting chemo treatments? If so, can you describe the changes?"

Participants experiencing menopausal side effects were asked:

- "If applicable, how long have you been experiencing menopausal side effects"?
- "If you are willing to share, when did you start experiencing menopausal symptoms"?
- "Can you explain how symptoms of menopause have changed how you sense hot and cold temperatures"?

All our interviews were digitally audio recorded and transcribed. The transcribed interviews were manually analyzed using affinity diagrams [14] and contextual tags to determine themes. Themes included contextual aspects of home temperature decision-making, including household occupancy, traditional techniques to saving energy, economic motivations, and conservationism. The open-ended survey question responses were added into the theme diagrams to get a better picture of how participants decide on home temperature within the familial structure.

4.2 Online Surveys

Initially, both surveys for cancer and menopausal participants were deployed using Google Forms. Participants were asked to consent to be a part of the study and then the survey questions were displayed. All survey questions were required to be answered.

The surveys included 29 closed and open-ended questions. The open-ended questions allowed participants to provide anecdotes, experiences, and present their own opinions regarding home energy management and usage. With this methodology, we were able to obtain quantitative and qualitative data.

Using Craigslist, Twitter and word-of-mouth, we were able to recruit menopausal participants for the study. Cancer participants were more difficult to recruit with these methods. We received positive feedback from several online cancer support groups and, via a contact generated, were able to partner with one to recruit participants. This online partner has elected to remain anonymous.

The online support group we worked with for participant recruitment requested that the survey be moved to SurveyMonkey and, thus, the cancer participants responded to questions via this tool. The cancer survey also contained 29 closed and open-ended questions. The demographic questions were the same, although the online support group requested some of the categories be modified to conform with their demographic groupings. For example, the cancer age demographic groups are 18-24, etc. where the menopause age demographic groups are 18-25, etc. (Table 1).

***Table 1: Significant** demographic percentages of study participants*

Demographic Distributions		
Age	***Menopausal Participants***	***Cancer Participants***
36-45	9%	11%
46-55	62%	29%
56-65	24%	44%
Income (Yearly)		
Under $15K	20%	19%
$15K-50K	30%	18%
$51K-75K	35%	18%
$76-100K	5%	15%
Education		
High School	19%	10%
Undergrad Degree	19%	32%
Grad Degree	9.5%	23%
Home Ownership		
Own Home	55%	79%
Rent Home	45%	20%
Other	5%	<1%
Type of Primary Home		
Single Family Home	35%	79%
Apartment	30%	12%
Townhome	15%	4%
Other (dorm, duplex, etc.)	15%	5%

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4.3 Participant Demographics

We recruited 22 households where at least one member was experiencing menopausal side effects and 114 households who have a family member with a diagnosis of cancer. All participants had to be 18 years of age or older. One person out of the household was interviewed or responded to the survey; that person did not have to be the person experiencing menopausal symptoms or receiving chemotherapy.

Participants were diverse across household income, occupant characteristics, and type of housing. Occupant characteristics include households that have different family members residing in the home. Participant households indicated that different types of people were living in the home, including children, spouses, boy/girlfriends, grandchildren and others. Having a variety of household types is important in order to understand the nature of contexts and complexities present within homes and how the differences affect home energy decision making.

The menopausal group consisted of 22 households within which one family member was experiencing menopausal side effects. Quotes from these participants are delineated by the letter ‘M’ before their participant number.

The cancer participant group included 114 households with at least one member either currently receiving chemotherapy, radiation or other drug treatment for cancer or a household member who has previously undergone drug treatment for cancer. These participant quotes are designated with the letter ‘C’.

To clarify, quotes specifying ‘self’ are those from a person experiencing the health event and those specifying ‘caregiver’ are quotes from a caregiver/household member,

All participants had to be 18 years of age or older. Cancer participants had to be currently receiving chemotherapy or another drug treatment for a diagnosis of: breast cancer, skin cancer, lung cancer, colon cancer, bone cancer, prostate cancer, or lymphoma.

Participants in both groups came from a variety of age groups with the majority of menopausal participants falling between 46-55 (Table 1).

Table 1 outlines the majority percentage of age distribution, distribution of age, income level, and education across both groups of participants. This distribution helps gain a better understanding of how a variety of people are interacting with their HEMS while also dealing with a health event.

4.3.1 Home Structure

Home ownership and type of primary home data (Table 1) was gathered to determine how many participants were easily able to make changes to their home’s structure and also to understand the physical structure of the building. The physical structure gives us an idea of how a home’s temperature is affected by external factors. For instance, in a multi-dwelling structure, heating or cooling may be impacted by the other units, whereas a single unit home would not.

Some participants commented on the structure or location of their home as a factor in how their HEMS worked.

> *West winds make it hard to regulate normally. I need to raise the thermostat to compensate for wind chill and drafts. It is a very old home (Participant M22, Self).*

These particular details (wind speed, age of home, tree coverage, etc.) were not gathered in this study but they do impact the efficiency of a HEMS and how family members perceive the home’s temperature. Future research with a system deployment may consider these external factors to assist with setting an optimal home temperature.

Along with home ownership and type of primary home (Table 1), roughly half of all participants indicated they have lived in their current home for more than 10 years (M = 55%, C = 49%). The other half were equally distributed between living in their current residence for less than 1 year to 7-10 years. The length of time within a home provides an understanding of how residents interact with their HEMS longitudinally. People living in the same structure for such a long period allows us to see how their HEMS has changed over time, how compromise has taken place over the years, and offers a more stable basis for current and future study.

4.3.2 Household Structure

Women were the primary respondents from both groups: 92% of the cancer participants and 85% of the menopausal participants. This is important to note since this research seeks to understand not only how the person who is facing the health event is dealing with home temperature, but how decision making is happening.

The majority of participants stated they had at least one other person living in the home with most (M = 57%, C = 82%) listing three to five household members, including family pets. Only 18 (n = 114) of the cancer participants and 3 (n = 22) of the menopausal participants said they lived alone.

The number of family members is important since it speaks to the level of complexity for compromise and decision making regarding home temperature. It also allows a view into any hierarchy that may exist within the home regarding setting home temperature. This helps with understanding the variety of contexts that exist in order to determine factors of potential HEMS features.

4.4 Participant Perceptions on Health Event Impact

Our participant's reports support past literature that these health events impacted their perception of hot and cold environmental temperatures [4, 29]. Due to their experiencing menopausal symptoms or from their cancer treatments, participants indicated a change in how they perceived hot and cold and correspondingly had to make adjustments for personal comfort. All respondents going through menopause indicated their symptoms affect how they sense hot and cold temperatures while 77% of cancer patient participants said their treatment affected their sense of hot and cold temperatures.

> *I get hot more often. I rarely turn the heat on. I use the air conditioning in the winter. I stick my head in the freezer sometimes (Participant M5, Self).*

> *Some days I have hot flashes, and some days I have chills, I try to adjust the temperatures in my house so I can avoid these symptoms (Participant M9, Self).*

Participants discussed the difficulty in setting a home temperature that is comfortable for everyone in the house. Their personal comfort and desire for a certain home temperature was often at odds with other people living in the home.

> *My menopausal condition is my greatest impact on how I interact, trying various ways to get that under control so others won't be uncomfortable (Participant M1, Self).*

One closed-ended survey question asked about participant coping mechanisms (Figure 2). For the participants experiencing menopausal symptoms, they often took control of setting home temperature (47%) while another 38% stated they took off or put on clothes to alleviate how they were feeling. Two mentioned more extreme measures of putting their head in the freezer (M5, Self), taking hot/cold showers, or having a cold drink (M18, Self).

Of the cancer participants, only 28% stated they took control of home temperature, while 40% said they took off or put on clothes to suit their personal temperature.

> *[I am] very sensitive to heat and cold. Everyone else will say that it's comfortable and I'll be freezing or everyone will say that it's not too hot and I'll find it unbearable. I'll feel my heart beating in my ears and feel like I'm going to pass out (Participant C45, Self).*

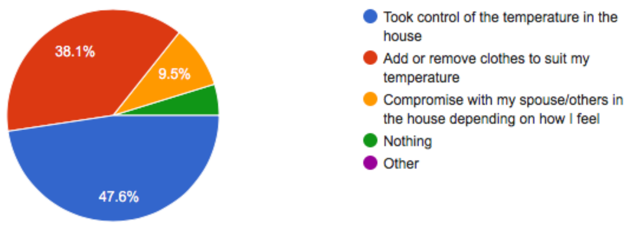

Figure 2: *Menopausal participants (n=22) temperature coping methodologies*

4.4.1 Health and Stress

Often a health event, particularly a diagnosis of cancer, brings with it a variety of emotions, including fear and guilt [20]. Li *et al* [20] explain that often the guilt is felt on both sides: the patient feels guilt for being sick and the caregiver feels guilt for not being able to cure the patient or take away his/her discomfort. Li *et al* [20] state that communication within families can be extremely difficult after a diagnosis of cancer and that some caregivers sacrificed their own needs and deferred to the wishes of the patient if the patient is able/willing to express their wishes.

Our study participants' remarks coincided with this phenomenon, which show that the person facing the health event often 'overrules' the other household members, meaning one person's comfort is ranked higher than the others residing in the home.

> *He tells me it is too cold in the house even when it seems ok or even warm so I sometimes have to turn up the heat on the thermostat when I otherwise would not (Participant C4, Caregiver).*

Within our study population, home temperature decision making had three configurations: (1) constant compromise; (2) individual coping mechanism (i.e., adding a blanket, using a personal fan) are used to feel cooler or warmer; (3) a spouse/caregiver makes changes based on their perception of how to make the patient more comfortable, which may or may not be a correct assumption.

Participants from both groups spoke about their health event impacts the dynamic between family members.

> *I noticed that it wasn't normally as cold as he would have put it. Like last night I was cold and he was hot. Instead of putting it down to 65, he put it down to 68 (Participant C1, Self).*

> *My boyfriend does not like the AC on because of the bill and because he isn't hot most of the time even though I am (Participant M2, Self).*

When it comes to dealing with a health event like cancer or menopause, there are already many stressors to consider, that often the heat and/or cooling of the house is changed on the fly based on a single occupant's wishes. Having a system that

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assists in decision-making, taking the burden off the caregiver, would alleviate part of the health event stress.

4.5 Interaction with Current HEMS

Our participant population indicated use of a large variety of thermostat models. Within our participants who knew their model of thermostat, most (M = 49%, C = 37%) said they had some type of Honeywell, while 4% of cancer participants and 7% of menopausal participants stated they had a Nest. A large percentage (M = 36%, C = 54%) stated they didn't know what model of thermostat was in their home.

66% of cancer participants and 55% of menopausal participants stated they had a programmable thermostat, although most stated the majority of their interactions with their system was still manual (M = 86%, C = 88%).

Our research speaks to the need to provide an easy and intuitive user interface to get people comfortable with the increased availability of connected devices as well as for these devices to "understand' why temperature changes are being or need to be made. This is particularly important when people are facing a health event like cancer or menopause. These specific health events are longer term than a cold or flu, so can speak to design considerations for a system that can provide optimal comfort for all residents.

4.5.1 Current System Availability

Companies have been capitalizing on the growth of the Internet of Things (IoT) to offer home appliances that connect to each other and to the Internet. The Nest thermostat, for example, can be programmed via a smart phone application while the Philips Hue system allows home lighting to be controlled collectively. Amazon's Echo system allows voice control to many home appliances, including lights, thermostats, fans, and garage doors [2].

Currently the state-of-the-art thermostat is the Nest thermostat, which is an example of a "learning" thermostat whereby its goal is to discover the occupants' schedule (whether at home or away) and adjust home temperature accordingly. At present, the Nest isn't completely effective at learning within a multi-occupant home [30]. Yang and Newman's [30] research shows that the Nest has difficulty with learning occupant schedules and occupancy sensing. In particular, they mention that the Nest does not do a good job with understand the contextual reason behind the home temperature changes [30].

Fifteen (15) participants mentioned in an open-ended question they would like to have the option of changing their schedule remotely, via a smart phone or other remote control, when asked the open-ended question "Can you think of anything else that impacts how you interact with your home energy systems"?

While this is not a large percentage of overall participants (n = 136, 11%), the fact that this option is on their minds as an improvement is relative to understanding current home energy system interactions.

How and why people make home temperature decisions is crucial when building a perceptive system that would improve occupant comfort levels. These considerations are important when household members decide on home temperature as it's not usually simply because one is hot or cold. In addition, challenging conditions exist when multiple family members have different heating and cooling needs, but they can be vague and uncertain as their body temperature fluctuates throughout the day, according to our participants.

> *It is just is all out of wack. I am hot when it is a little chilly chilly when it is a nice room temp; I am all over the place temp wise" (Participant M7, Self).*

After defining a "smart" home thermostat, our participants stated they believed that having such a technology would improve their daily lives (M = 86%, C = 62%). The challenge is having a system that is intuitive and provides easy interaction.

Yang and Newman [30] ascertained that users did not reprogram their "smart" thermostats when their schedules and/or situations had changed. Therefore, our research suggests implementing the ability for a system to adjust itself according to contextual factors. "In the versions of the Nest that we studied, the subsystem that learned user preferences was only capable of detecting one aspect of user behavior (control changes) and the system provided no convenient mechanisms for indicating which inputs ought to be remembered by the system and which ought to be forgotten. Additional relevant dimensions of user behavior such as occupancy, the presence of particular household members and guests, and household activity levels as well as contextual dimensions such as humidity, external temperature, and sun exposure—all of which could be relatively easily sensed and incorporated into a predictive model—were simply not included, and there was no mechanism for compensating for their absence [33].

There are technologies that seek to simplify the interaction with one's HEMS but even with a programmable thermostat, the instructions aren't completely clear or the users do not take advantage of the options available.

> *I have a basic understanding of how to change temperature; a more in depth understanding may make the unit work better for us (Participant C82, Caregiver).*

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Even with a thermostat that offers a smart phone application, participants indicated they often continue to simply use the dial or buttons on the thermostat itself due to the simplicity of the action. This indicates the need for other interaction methods that consider the dynamic nature of family schedules.

> *My current system can be controlled from a smart phone, but most often we use the thermostat (Participant C11, Self).*

Current "smart" thermostats that can work with a programmed schedule are not often intuitive or they require the user to use a smart phone application or web site to make changes. Considering the dynamic nature of households, an interface that can perceptively assist with decision making without the inconvenience of having to manually reprogram the system.

> *I would like to have something that I could turn on from away from home so I can keep the temp low/high when not there, and kick in the furnace/AC before I get home. My hours differ, so programming is not enough (Participant C26, Caregiver).*

Our study participants indicated they would like a system that would know when they are home and change based on how they are feeling during the day.

> *It would be nice to be able to go away for a vacation, save energy, and then be able to adjust the temperature remotely so that when I return the house is already at a comfortable temperature (Participant C87, Caregiver).*

> *A lot of the times I feel very warm/hot when others are feeling comfortable and I start to sweat; and then some of the time I feel super cold and others in the house feel warm enough and comfortable (Participant M1, Self).*

Participant acceptance and the accuracy of systems such as TherML [14] which predicts home return time for HEMS, shows that an automated system can have success within the home environment. TherML [14] uses GPS coordinates from a smart phone application to predict an estimated home arrival time to adjust temperature to optimal levels before the occupant sets foot in the house. This technology illustrates the ability to set temperatures while away, which our participants stated as a desire, but does not allow for contextual inputs while already in the home. For example, being able to set an appointment time and date for chemotherapy or other pre-scheduled event.

5. IMPLICATIONS FOR SYSTEM DESIGN

5.1 Implication #1: Naturalistic Decision Making

Participants discussed the difficulty of dealing with fluctuating temperatures as a result of their health event.

> *Because chemo caused neuropathy I can't feel hot or cold in my hands very well. Overall during chemo I was always cold, I couldn't get warm. Chemo put me into instant menopause, so now I'm hot a lot of the time because of menopausal symptoms (Participant C44, Self).*

They expressed the desire to have a system that is easy to program and keep updated.

> *It is convenient that it can be controlled from my smart phone. I am often fatigued and this makes things easier (Participant C78, Self).*

> *For me, other significant impacts include ease of use and ease of maintenance, including ease of installing (software) upgrades to a smart system (Participant C11, Caregiver).*

Using naturalistic decision making (NDM) within a HEMS would assist the family in setting a temperature that would respond to changing temperature scenarios, thus providing greater ease of use. NDM has been studied in various fields and scenarios, [6] to discover how non-routine challenges are processed. Participant feedback suggests that utilizing these theories and applying appropriate contextual data, NDM can be built into the perceptive system to adjust temperature accordingly. The stress of having to communicate and compromise between household members could be removed since the system is making decisions based on pre-programmed information.

> *I would love a system that could adjust to me during the day. I have hot and cold spells and it can be frustrating. I would also love to be able to adjust it from my smartphone. That would be an awesome benefit (Participant C87, Self).*

5.2 Implication #2: Including Voice Command

Five (5) participants expressed interest in being able to control their HEMS with voice commands. This low number may be reflective of the relatively new and limited availability of "talking" to one's home. A voice command question was not specifically asked in this study as a means to discover participant wants/needs without providing suggestions.

Adding voice commands to current thermostat technology could ease programming and aid in using system features. In this way, the family has a simpler method to interact with their HEMS, which has the potential of easing decision-making within the household. The user would not necessarily have to learn how to program the system but would be able to ask the system to make changes in natural language.

> *I would like to be able to interact with via voice commands and via smart technology locally and remotely (Participant M11, Self).*

Since voice technology is widely available in smart phones, the learning curve is relatively palatable, within a HEMS, it can be leveraged to improve user acceptance. As participant C37 stated, their

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household uses Amazon's Alexa [1, 2] voice technology to assist with interactions with home appliances.

> *We also have voice technology that I could control the temp but I am not often in the room that has the main control (Amazon's "Alexa"). All in all, it's been a tremendous help with not a huge amount of cost (Participant C37, Self).*

Conversely, voice technology could add another dimension of stress to the situation if the system does not properly understand participant commands, continually requesting a repetition of the command. Additionally, some people could find "talking" to their homes awkward and unnatural. In either case, a system that is not easy to interact with will be quickly abandoned.

5.3 Added Functionality: Temperature Monitoring

People receiving chemotherapy may experience 'flu like symptoms' which can include fevers and chills. These may be a normal side effect of the drug treatment [17] and should be monitored closely after returning home. Cleveland Clinic, a leading cancer care organization, recommends that patients notify their physician immediately if they have a fever of 100.4° F (38° C) or higher, and/or chills (possible signs of infection) [3]. As such, taking personal temperature would be beneficial to both the user and the thermostat.

This is especially important for situations when a person has to monitor his/her temperature and reactions to said treatment and report back to the attending physician or other healthcare worker. If collecting this information can at least be partially automated, the data provided would likely be more accurate and contain pertinent details, which could benefit future treatment plans.

As the consumer market has shown, people have embraced the usage of wearable technology. From heart rate monitors to walking step counters, people have become fond of self-tracking. In light of this, a wearable technology to take temperature is ideal.

Using an in-ear model temperature sensor (figure 9) would be less intrusive and also foster compliance for this important step in patient care. Since the in-ear model is similar in size and shape to the now ubiquitous headphones, the user is more likely to wear it while going about his/her daily routine within the home. Unlike other methods of taking temperature (oral, anal, or hand held in-ear device), this method doesn't require the user to stop whatever he/she is doing to get a current measurement. It also doesn't require the user to take note of his/her temperature for later reporting to a healthcare provider. It would automatically record the person's temperature for personal review or by a physician. Eliminating extra steps may improve patient compliance of healthcare provider directives.

The data collected can be exported to a CSV file so can be easily analyzed. Because the device also tracks distance, movement in the house can be inferred and correlations established. In this way we can see how much movement is happening, the user's temperature, and how that effects their temperature choices.

Figure3: *cosinuss in-ear sensor [5] syncs with applications available for both smart watches and phones*

6. SUMMARY AND LIMITATIONS

This work provides insight into how people facing a health event such as menopause or cancer make decision regarding home temperature in relation to the other household members. By gathering data from a wide variety of participants (M = 22, C = 114), an understanding of how people deal with fluctuations and change within the home regarding their HEMS is provided, along with 4 implications for design for future use. These implications may provide an easier method for compromise within the home in general as well as relieve stressors implicit in dealing with any health event.

Speaking to just one member of the household limits the work in that only one perspective was gathered, even as to the thoughts and feelings of other household members. Another limitations is the fact that participants indicated they were often eager to accept the status quo within their homes and not eager to introduce another level of change or stress in the form of a new HEMS. This could have influenced their responses to the questions about changes to system design.

In addition, there are organizational constraints since budgetary issues that may come into play such as if a person is renting or owns their own home or if they feel changes may negatively impact their family budget. Home construction may limit availability of some heating and cooling options. For example, if a home is not well insulated, the HEMS may not be as effective at meeting individual or collective needs.

7. FUTURE WORK

Future work could include interviewing several families who have a household member experiencing a health event to see how the group understands their decision-making dynamics in regards to home temperature. This would allow researchers to garner a holistic view of the household structure and to see how these implications for design would impact a wider population

Exploring system prototypes to study how people interact with and react to this type of technology within their homes is another avenue for future research. Presenting various configurations of the interface to allow participants to step through programming the temperature for the home and colleting feedback of their perceptions of the system and its impact on family dynamics would assist in further understanding how systems can assist with decision making and help alleviate stressors within the home.

8. CONCLUSION

To assist in decision making, home energy management systems should understand the dynamic nature of household structures. This research speaks to the building a home energy system that is intuitive to use and able to assist in familial decision making in order to alleviate part of the stress of a family member going through a health event.

Through surveys and semi-structured interviews, this research speaks to three design considerations for a perceptive home energy management system for populations facing a significant health event: menopause or a diagnosis of cancer. These considerations are: adding voice command options to the thermostat, adding naturalistic decision making within the system, and adding the ability for the system to interact with personal temperature monitoring for both health and personal comfort.

Understanding these populations will enable the creation of systems that are useful to the wide variety of familial structures, including those who are facing a health event. These features and functions of a home energy management system consider the dynamic nature of households and presents a perceptive system that will enable a more dynamic interaction and improve household decision making.

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