Can you please cover both the "smart" and the "home"? Exploring expectations on smart homes considering changing needs

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ABSTRACT

The number of connected devices in-home has increased rapidly, and connected solutions in smart homes do not yet cover needs of all inhabitants. We explored future interfaces that blend seamlessly with the home interior in co-creation sessions with people from diverse co-living situations. The results contribute to acknowledging a home's complexity considering shared households as places where many needs meet and possibly contradict each other. Based on findings from three workshop sessions with a total of 12 participants, we present two themes of relevance when designing for smart homes. Covering both, a smart home can adapt to users' needs and become valuable members of multi-people households while maintaining the characteristics of a home for all individuals.

CCS CONCEPTS

• **Human-centered computing → HCI theory, concepts and models**.

KEYWORDS

smart homes, shared households, user needs

ACM Reference Format:
Annika Sabrina Schulz and Eva Hornecker. 2022. Can you please cover both the "smart" and the "home"? Exploring expectations on smart homes considering changing needs. In *21th International Conference on Mobile and Ubiquitous Multimedia (MUM 2022), November 27–30, 2022, Lisbon, Portugal.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3568444.3568447

1 INTRODUCTION

Being constantly online has become the norm for many people, leaving many individuals with the feeling that they need to reconnect with the analog world. Individuals are striving to use technology more consciously as they spend more time with remote work, home schooling, and social media [58]. Digital tools are being developed to address this need in virtual environments, such as the popular genre of "satisfying videos" that emerged on streaming platforms conveying sensory experiences that evoke emotional reactions and a sense of connectedness [58]. In addition, consumer technology companies have taken note of this societal shift by developing more subtle technologies. TV providers, for example, are working on ways to eliminate the "black hole in the interior" of the TV screen by displaying art in stand-by mode [60]. In 2019, IKEA established an official business unit for smart homes to collaborate with technology providers on future devices that blend in seamlessly with home interiors [1]. However, interaction in the smart home sector does not represent this perspective yet, and has thus far focused mostly on increasing comfort and efficiency in terms of energy consumption, leaving further user needs in the context of the home neglected [25, 26, 50]. The most popular devices to control connected appliances are speech assistants or smartphones [11], although both might come with negative consequences in everyday life. Smartphone use has been shown to negatively impact interpersonal relationships in social situations [14]. The same might hold true for voice assistants, as using voice commands to direct a virtual assistant can disrupt or cut off concurrent social interactions between people. However, homes are inherently social places, usually shared by multiple residents caring for each other and managing conflict [25, 33]. Currently available smart home solutions do not reflect the nature of homes in terms of shared use, presenting the home as a place where people have stable needs without any conflicts [25]. Some authors explain this gap with the expert view on the developments in the IoT domain [13] and too little user diversity in investigated scenarios [25, 50].

In the future, the physical world will merge even more with the digital [22, 31, 57]. We approach the design of future smart home interfaces with the vision of using smart surfaces that blend seamlessly with home interiors (cf. [1]). Therefore, we conducted virtual co-creation sessions with 12 participants (mostly female) living in various types of shared households to envision analog inspired surfaces as user interface for the smart home network. We used context-mapping [54], which is a combined method of cultural probes [23] and generative research workshop sessions [42]. Analyzing the discussions on how the participants envisioned smart surfaces both on a semantic and latent level using thematic analysis [10], we discovered that smart homes need to incorporate two themes at all times so they can dynamically adapt to users' needs depending on the context.

Based on our insights we describe how smart home systems could be designed so they are appealing to all individuals in shared households. This research contributes to the development of interfaces considering diverse users that typically come together in shared households. Here the different dimensions of everyday life

MUM 2022, November 27–30, 2022, Lisbon, Portugal

ACM ISBN 978-1-4503-9820-6/22/11.
https://doi.org/10.1145/3568444.3568447

and the fact that a home is a place shared by many people for communication, various activities and distribution of house labor are taken into account.

2 RELATED WORK

Early literature on ubiquitous computing gathered demands concerning connected devices moving from offices to domestic environments [15, 19, 52]. Edwards and Grinter formulated resulting challenges for homes with ubiquitous computing covering technical, social and pragmatic domains. In conclusion, they hint towards the design challenge of balancing technological capabilities of a smart home with the users' desire to feel at home in such environments [19]. One question contains, for example, where in the home ubiquitous computing devices should be placed in relation to existing routines of residents [15, 52]. Today, smart homes are typically associated with comfort and efficiency achieved through the Internet of Things (IoT) by connecting devices [9, 25, 29]. As a result, the emphasis is on automating the home around the humans who live there, without knowing and addressing actual user needs [6]. In literature which covers IoT, most work focuses on improving technical aspects through automation [32]. The term "smart home" has been established as a synonym for "smart building", indicating a lack of user-centricity [25]. This might have led the experts to inadvertently exclude residents from future energy-efficient homes by designing automation that avoids human intervention [13].

However, operating a smart home inevitably leads to the need of users to interact with their smart home system and include it in their routine. At the very least, tasks related to setting up and maintaining the network, which Tolmie et al. characterized with "digital housekeeping", requires respective interfaces [52]. Yet, the home automation domain seems to overlook the people who live within the buildings. Thus, interaction paradigms established that disconnect users more and more from the physical world [9] and alienate people from their domestic environment [13, 25].

Devices with touchscreens (e.g., smartphones) or voice assistants are the most common commercially available interfaces for smart homes [11], even though neither interaction form is appropriate in all situations. To counteract the dematerialization caused by voice and touch interactions, several researchers aim to work on creating interfaces that require less cognitive load [12, 34, 47]. Tangible interaction seeks to leverage natural human skills for interactions with digital information while also providing more intuitive gestures that require less time to learn [47]. To accomplish this, researchers frequently design devices in a way that they resemble analog objects with physical affordances [48]. With advances in material science, blending interfaces better with furniture becomes more feasible [38, 39]. However, there is a lack of human-centered approaches in combining the two fields.

An analysis of smart home literature in relation to the societal concept of the home revealed a divide, where technical publications focus on use cases that involve security, control, and activity tracking. In contrast, conceptual work investigates the relationships, values, and identities of smart home users [25]. We found similarities in the literature on user interfaces for smart homes: authors often describe the design and development of universal interfaces from a technical standpoint [18, 29, 51], whereas researchers who focus on human needs create user interface designs for particular applications [21, 35]. Williams et al. explored how families collaborate in dividing house labor. Further, they investigated mental models of the home and how they are in tension with current IoT systems. In conclusion, they suggest the inclusion of upcycled objects as IoT devices to support users in expressing themselves [59]. Takayama et al. investigated how technology can be used to create more "homey" environments, and identified values that are important to users [50]. However, their participants were primarily male smart home users who live alone [25].

We investigate the requirements for interaction with connected devices in shared households from individuals (mostly female) living with flatmates, partners, and children to reveal shared use needs.

3 STUDY DESIGN

We took a co-creation approach, asking the participants to fill out cultural probes before attending an online workshop. In three workshops (independent of each other) with four participants each, we used ideation methods to inspire participants to envision future interfaces for the smart home which blend in with the interior. As general approach we used context-mapping, a qualitative research activity that consists of two phases [54]: 1) cultural probes, 2) following co-creation sessions. The first phase serves to mentally prepare and sensitize participants for the topic of discussion and to engage with exploratory tasks before taking part in the co-creation session.

Cultural probes are tasks designed to playfully pique participants' curiosity and can be presented in various physical ways, including maps, postcards, and other materials [23]. In the second part of context-mapping, generative sessions are conducted in which participants create and subsequently explain artifacts [54]. The creation of artifacts allows participants to become aware of tacit and latent forms of knowledge, enabling them to share their experiences on a deeper level, including information from their past and wishes for the future, such as their world views, attitudes, and dreams [43].

3.1 Sensitizing Participants with Cultural probes

For the cultural probes we prepared illustrations of six distinct living areas of a home including pop-up paper elements to highlight storing surfaces and tasks, that we sent via post to the participants' home. This enabled participants to reflect on their own behavior with regard to those areas, so that they could consider past and present experiences while envisioning smart home devices intermixed with their current practices in that area. Concretely, we asked the participants to sketch common portable items in the provided illustrations. Further, they were asked to highlight associations with specific actions, if the item is always placed in the same location, and if the storage surface is shared with other people. Participants were given 10 days for this task and then asked to return the filled-out probes via post. The probes were not discussed in the co-creation workshops, as they were designed solely as a pre-workshop priming exercise. Further details on the used Pop-Up probes can be found in [46].

3.2 Co-creation session

The second component of the context-mapping study was a set of co-creation workshops where we discussed with participants what universal smart home interfaces blending with the home's interior might look like. Initially, we tested the workshop procedure in a six-person pilot workshop. Steps that were difficult or misunderstood were improved, resulting in the process described here. As the pilot is not relevant for the remainder of this paper, we focus on describing the procedure of the actual study. In total, we scheduled three online workshops with four participants each for the co-creation sessions. Two hours were allocated for each workshop session. Miro [5], a browser-based collaborative whiteboard, was used in conjunction with the video conferencing tool Microsoft Teams [2].

The co-creation session began with a warm-up exercise to (1) encourage participants to explore the functions of the whiteboard and (2) become acquainted with each other and their role as participants sharing personal experiences. Subsequently, we briefed the participants on interacting with everyday objects on top of surfaces with embedded contact-sensing technology to detect an everyday object in touch [44]. Therefore, we described the surfaces as resembling analog storage items they are familiar with, such as trays or table sets. To inspire the participants and build the connection to the tasks in the Pop-Up Probes [46], we provided a collage of decorative surfaces from various areas of the house (see Figure 1). We chose to reference only analog surfaces as inspirational material to avoid narrowing the ideation due to assumed technical limitations, similar to Andersen's and Wakkary's approach in "Magic Machine" workshops [8]

To reduce the complexity of the interactions, we described trigger-events inspired by the basic idea of tangible interaction [28, 47, 51, 53], in which placing an object on top of a surface would cause an event in the smart home to occur. In one instance, users could place an object on a smart surface to activate specific light settings, turn off the alarm system, or to play media. In the first hands-on task, we asked the participants to depict how they imagined smart surfaces. To give some guidance in the discussion, we provided notes on characteristics to take into account: Envisioning smart surfaces in their own homes, the participants should think of the living area and situations, who would use the surfaces, how it would look and feel like, as well as what objects could be used as triggers. The participants were sent into virtual breakout rooms, to discuss for private, off the record discussions in pairs. Afterwards, each group presented their ideas to all participants back in the main session of the video call.

The second part of the co-creation session focused on anticipated interactions with the envisioned surfaces. Participants were not trained designers, therefore creativity techniques were used to guide them [42]. Initially, we presented three stages of the manipulation of everyday objects on an interactive surface to the participants to ideate and explore expectations on tangible interactions. The following questions were addressed in this exercise: 1) how users can define an everyday object as a control object on the surface, 2) how users can manipulate an object to interact with the surface, and 3) how users can determine if the interaction was successful. The three stages were inspired by One-Step-Journey Storming' [49]:

Figure 1: Collage of analog surfaces in the home as inspiration for future smart home interfaces (created of free images provided by photographers on Unsplash.com).

one person presents the first step of a user journey and the next person in a circle fully accepts the idea and describes the next step. In the virtual setting, we modified this method to a brain-writing procedure derived from the creativity method '6-3-5', in which 6 participants would submit proposals on a given problem in a three-column idea sheet. After 3 minutes, they pass the sheets clockwise to the next person extending the ideas within 5 iterations [16]. We transferred the method to a virtual environment and adapted it to the size of the participant group. In preparation for the workshop, we created four dedicated areas on the collaborative whiteboard, one for each person. The participants were asked to brainstorm for 5 minutes on the 3 stages of the user journey we presented and then move to the next whiteboard area repeating the procedure three times. Accordingly, the adapted procedure resulted more in a 4-5-3 method. Following, we discussed with the participants the ideas they generated.

3.3 Participants

A total of 12 people (11 women and 1 man) took part in the series of three workshops, with a total of 4 participants in each of the three workshops. We followed a purposive recruiting procedure for the workshop participants using snowball sampling via e-mail and social media, targeting people who are not professionals on the Internet of Things (IoT). Because all participants in the first and second workshops worked for large engineering corporations, we consciously recruited participants from other professional environments for the third workshop. Furthermore, we took care to recruit people living in various living arrangements. Our goal was to bring in multiple perspectives by assuming our participants will have their co-habitants in mind and consider indirect stakeholders (e.g., flatmates, partners, children, and other family members) as well as to gain insight into how residents feel about ownership of areas in their homes. The gender ratio was not intentional but a side effect of recruiting participants without professional IoT backgrounds working in large engineering companies. Table 1 contains more detailed information about participants; the first mentioned ages concern participating residents, the latter their co-habitants. With the participants' informed consent, we recorded video and audio of the online workshops for the later analysis. All participants

were native German speakers residing in Germany, therefore, the workshops were conducted in German.

3.4 Analysis

To avoid rationalizing the content of the probe information as suggested by [24]. We did not analyze the returned Pop-Up Probes. However, all participants filled out the Pop-Up Probes as intended. We performed an inductive Reflexive Thematic Analysis on the transcribed discussions in the co-creation sessions, where participants envisioned future interfaces for the smart home and documented our procedure along the six phases suggested by Braun and Clarke [10]. To familiarize ourselves with the data, we listened to the recorded audio of all sessions, transcribed them in MAXQDA [4], and reviewed the data from the workshops on Miro [5].

Multiple iterations were performed, coding the transcribed workshops first semantically and in later iterations, on a latent level. Semantic coding helped to familiarize with the data in more depth by engaging with it first descriptively, before moving towards interpretation. Quotes tagged with latent codes were then sorted into subgroups, and used to generate initial themes. Resorting and visualizing the information in affinity diagrams and mind maps helped consolidate the key statements and find connections. Reengaging with the data like this helped to review the themes, discarding, or merging some during this process. We then defined themes by describing their scope and differences, first through mind maps to explore their connections. Since it is not possible to analyze data without facing personal biases [10], the analyzing person is shortly described: She identifies as female and has a Central European cultural background.

Several participants used the German adjective "wohnlich" (in English "cozy", although this word does not fully translate the word's meaning, which is closer to the Danish "hygge") descriptively to summarize desired characteristic for future technology in workshop series and covered one aspect of our initial themes, so we re-involved the workshop participants and asked them for their personal definition of the term. They were asked to provide bullet points and send photos of areas in their homes with that property. This activity supported reviewing initial themes, and crosschecking the analyst's interpretation of the data. 10 of the participants provided their definitions. Throughout the whole analysis, we used German working titles to avoid changed meaning by translation. Only after writing them up in text supported with quotes, the themes were translated and named.

4 INSIGHTS AND DISCUSSION

We report our findings on both a semantic and latent level. First, we describe how the participants' envisioned smart surfaces that appear like analog ones, being confronted with the idea of tangible interaction with everyday objects. Subsequently, we present the two themes *"smart home should feel like home"* and *"smart homes should contribute actively to the household"*, and how they spread in various aspects when designing future smart home devices and interactions.

4.1 Expectations on interaction with smart surfaces that appear "analog"

In the workshop series, participants ideated on the interaction with surfaces that appear analog to control smart home devices. We describe how participants expected trigger-event interactions using everyday objects being placed on top of smart surfaces, and looked into detail how the participants imagine to define everyday objects as triggers, manipulating the objects on the surface, and feedback mechanisms. This description serves as an example, how future devices could be designed in a way that participants perceive them in balance with both themes, fulfilling their function as smart home component, and as element that make them feel at home.

4.1.1 General characteristics. Envisioning interactive surfaces in the home, participants initially thought of them as integrated *"control panels"* in sofas or coffee tables, or as *"central hubs"* in various areas. The size of smart surfaces participants imagined comparable to the analog surfaces (e.g., decorative mats or trays); large and flexible surfaces, for example in the size of a tablecloth, were difficult to imagine. However, their creativity might have been narrowed by the inspiration we presented them in1. Despite an analog look, participants highlighted that smart surfaces need to be clearly distinguishable from non-interactive ones. Differences could be intensified in the haptic properties of the surfaces. Overall, they had no clear vision for the feel of the surface, besides that it has to be pleasant for users to touch. What this exactly means is highly dependant on an individual's preferences and the context. W3P1 explained *"The material of the surface depends on what kind of object I put on it - and also on the room. In the bedroom I would not like a glass plate. That looks uncomfortable, then maybe rather a piece of wood, or something woven, or something made of cushions"* asking to consider the context of use for future interfaces, differing between areas in the home

4.1.2 Interacting with Smart Surfaces. Regarding setting-up smart surfaces, participants feared that *"programming the individual objects, and assignment of different users will be time-consuming"* and in that case it would be *"perceived only as a gimmick"*. Most of all they would like to have the surfaces as plug-and-play solutions with already defined trigger objects being included in the purchase. Alternatively, they imagined to include external devices to the interaction such as smartphones and take a picture of the new object to define it as control element or refurnish the objects by attaching something to them. Other ideas concerned the design of the surface itself. The participants expected for example a signified area in which users should place an everyday object or *"perform a choreography with the object"* to connect and *"wake the surface"*. Several participants envisioned the surface changing between an activated and a deactivated status. Along with this idea, they described the surface having *"multiple zones"* from which the objects could be moved. Manipulating an object *"from zone A to zone B would trigger an event. Moving it back from zone B to zone A would stop it."* More specifically, one participant described this interaction based on the example of a smart surface on a coffee table: When the object would stand on the surface, not the whole surface would be activated. Looking at the coffee table from the right side, only the

Table 1: Participants' demographics

Participant	Gender	Age of Residents	Professional Environment	Housing Situation
W1P1	female	30 and 37 years old	Large engineering company, Home Office	Semidetached-house, 2 people (couple), 2 cats
W1P2	female	29 and 36 years old	Large engineering company, Home Office	Rented flat, 2 people (couple)
W1P3	female	47, 52, 16 and 18 years old	Large engineering company, Home Office	Homestead, 4 people (2 parents, 2 teenagers), 2 cats
W1P4	female	26 and unknown years old	Large engineering company, Home Office	Rented room in shared flat, 4 persons (just moved in)
W2P1	female	34 and 3 years old	Large engineering company, Home Office	Rented flat, 2 people (single parent with toddler)
W2P2	female	23 years old	Large engineering company, Home Office	Rented flat, 1 person (temporary for 6 months, usually room in shared flat)
W2P3	male	30 and 28 years old	Large company, Home Office	Rented flat, 2 people (couple), 1 cat
W2P4	female	52 and 54 years old	Large company, Home Office	Rented flat, 2 people (couple)
W3P1	female	25 years old	Civil office	Rented flat, 1 person
W3P2	female	32 years old	Medium-sized company, Home Office	Rented flat, 1 person
W3P3	female	26 and 32 years old	Medical office	Rented flat, 2 people (couple)
W3P4	female	30 and unknown years old	Medium-sized company, Home Office	Rented room in shared house, 5 people

left side would be activated, and users could trigger events by moving the object in that area (e.g., sliding an object across the surface to lower or rise shutters). The participants expected to configure the position of the zones individually, depending on their position, if users were right-handed or left-handed and personal preferences. However, several participants explained tangible interactions with everyday objects as control elements appears not as the easiest way to interact for them — touch or gestural interactions seemed more intuitive to them.

The expectations on feedback from the surfaces included different variations of light sources integrated in the surface or parts of it (e.g., edges), such as displaying geometrical figures underneath the object they placed on top. Visual cues could also include patterns, as flashing or lighting up. Some participants would expect continuous light if the surface is activated whereas others expect the lights to turn off after a short time. Continuous light, they proposed, would offer the possibility to communicate additional information (e.g., battery status). Alternatively to light cues, the participants imagined changing structures of the surface, e.g., switching between a smooth and a grooved structure. Visible movement during changes between both structures could signify loading times. Also tactically, the participants imagined to feel the shape of sliders by increasing the perceived resistance above specific thresholds or indicating barriers. Grooved structures could thereby provide guidance to move objects. Further ideas regarding haptic feedback of the interface included the feeling that the object would adhere to the surface or have a magnetic pull. The pull was envisioned specifically for the moment of placing the object onto the surface until it engages. This could convey a feeling that *"the object snaps in"*. One participant described that the surface could straighten out the orientation if objects were not placed symmetrically, a satisfying element for users. Conclusively, participants asked for an *"analog feel of the surface as with buttons"* and *"the feedback like with a real button so that they realize they have done something"*.

4.2 Covering two latent themes

As described earlier in the Study section, we analyzed the transcribed workshops also on a more latent level that provide insights on user needs for smart homes on a more general basis. We generated the two themes *"smart homes should feel like home"* and *"smart homes should contribute actively to the household"* based on the transcribed discussions of the workshop series, that both need to be covered in users' expectation of smart homes. We highlight here again that most of our users were females of which most shared the home with other people. The RTA [10] was performed by a female researcher who shares the same cultural background with the participants and views the data from a feminist perspective. This claim is in line with current literature, pointing out to a lack of consideration and participation of female identifying users for smart home [20, 26, 40].

The two themes we constructed provide thereby not a range of two concepts between which a balance needs to be found, but rather two key criteria that need to be covered both in the design of future smart homes. Here, the challenge lies in the complex nature

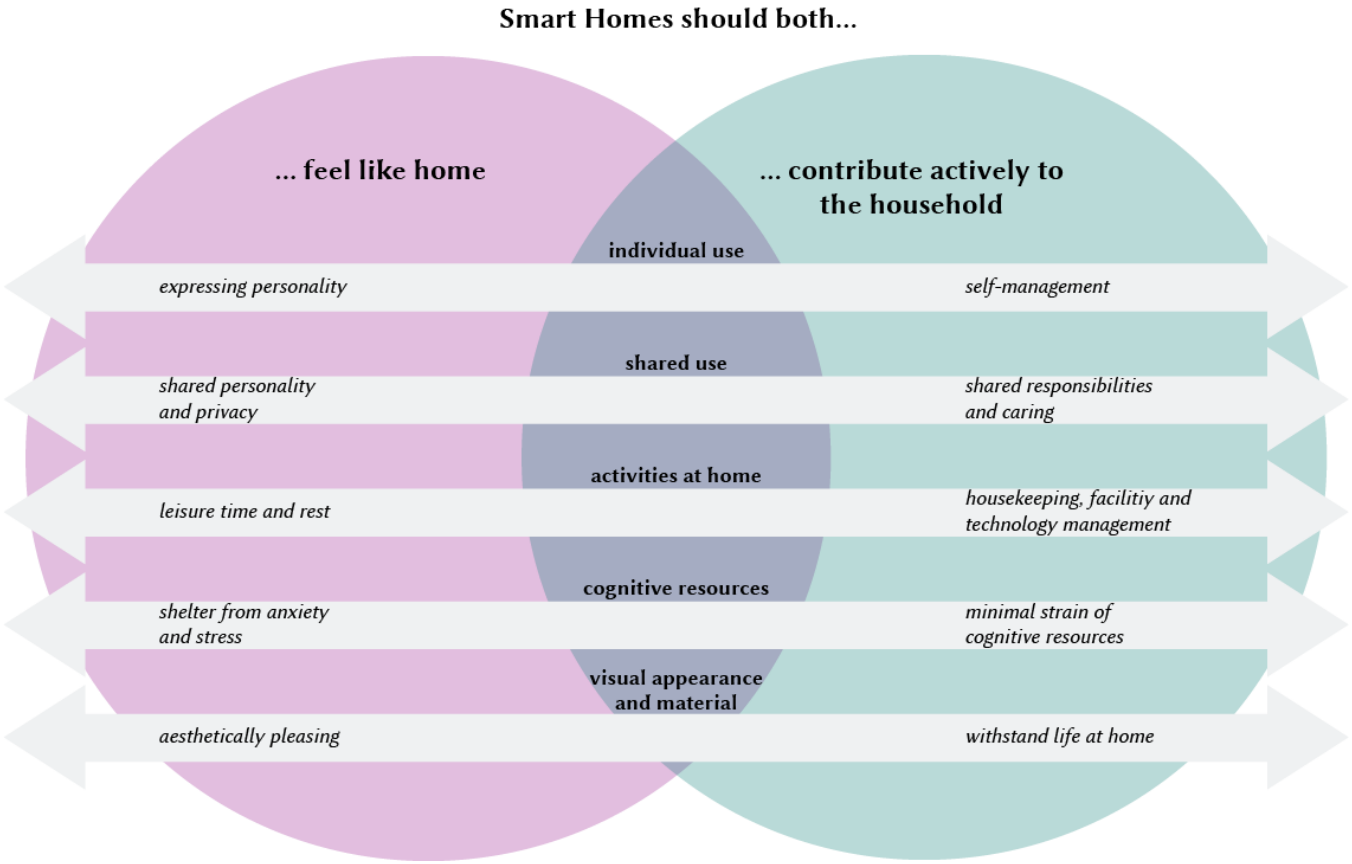

Figure 2: Relation of theme 1 and theme 2 and their expression across five topics.

of homes where preferences and needs are not stable but dynamic, sometimes changing rapidly from one side to the other [26]. On top of that, a home is typically a shared space in which multiple needs come together [25]. For some time, for one single user, smart home services covering a defined balance by design between the two themes might be sufficient. However, co-cohabitants or visitors could feel uncomfortable with the technology. Considering social influences, the needs of the primary user might change as well. Therefore, smart homes need to cover both themes completely and adapt the balancing to contexts and users.

Figure 2 presents the two themes in a Venn diagram including five aspects displayed in the overlapping area of both: individual use, shared use, activities at home, cognitive resources, and visual appearance and material. The five aspects represent topics that the participants described in the workshop series, each possible to stretch towards both themes.

The theme "smart homes should feel like home" is centered around the German adjective "wohnlich", describing the ultimate characteristic humans want to shape domestic environments. In a dictionary, the term defines environments that are "equipped in such a way that one likes to stay there, likes to live there and feels comfy, cozy, comfortable" [3]. For our participants, it describes the feeling aroused by the presence of personal items or associated with their past-time activities (e.g., books, piano), spending time with family and friends, as well as cozy interior.

The other theme "smart homes should contribute actively to the household" concerns the fact that smart homes are often advertised for increasing comfort and making lives more efficient. Our participants expressed concerns that this promise cannot be fulfilled but instead result in increased chores at home. Thinking of Artificial Intelligence in combination with "smart" technology, humans pose high expectations on the performance and capabilities cross-functionally, similar to inviting another human to live with them.

4.2.1 Individual use. This topic refers to personal requirements our participants posed on smart home technology. Participant W2P4 summarized: *"When we have something digitized at home, we always have the fact that everyone has their preferences and that it has to be personalized"*. To feel more like home, expressing their personality in setting up a smart home could help as people do in decorating their homes, for example by altering the appearance of physical and digital elements. *"I have a flower wreath on which I look exactly when I'm here in the home office, hanging on a wall opposite me"*, one participant (W1P3) said about an object important to her. *"It's made of hydrangeas from my garden. Or, rather, the hydrangeas come from me, but my mother has taken over the weaving. It's been*

hanging here for a long time." At the same time, smart homes are expected to provide practical benefits by supporting individuals in managing themselves. This would include for example to keep track of personal appointments, tasks, and chores. W1P3 described a situation where she could use technological support: *"In my home office, I always search for my computer mouse, because it always disappears, because my children took it and then I have only the dongle and the mouse been gone."* W3P4 imagined the smart home to know her and fit her mood in the morning: *"When you open the closet door, the light may go on or music because it knows, there you are, awake and feeling fit"*.

To meet the individual needs of users, smart home devices could be provided with multiple visual appearances to choose from, or different covers for devices. Addressing users with their names or using avatars could help to address the individualization virtually. Integrating content from external services they already use and adding personalized recommendations can enhances everyone's personal space. Approaches to individualize technology have been studied previously, for example in [7, 59].

4.2.2 Shared use. As most homes are shared environments, accommodating multiple people and receiving visitors, smart home technologies need to be suitable for *shared use*. To make multiple people feel at home, the characteristics users take when being in a group should be considered. This might among others depend on the areas of the home. W1P4 pointed out that *"the kitchen is really a communal space at home"*. At the same time, for individuals the matter of privacy arises when they meet others. *"In the bathroom, everyone has their own compartment where their toothbrush is placed"*, W1P2 named an example. In shared household and shared lives, social interactions occur that include caring for each other as well as conflicting situations, the need to find compromises and to distribute responsibilities. W1P1 gave as example: *"My boyfriend has different wake-up times, so I can't mess around with light and voice control in the morning"* and *"if someone is still sleeping, or has a hearing impairment, these are all things you have to be considerate of"*.

Overall, social behavior should be nudged and communication channels, synchronously and asynchronously as well as options to share information need to be established as integrated element of the smart home to facilitate co-habitation. Approaches how to establish such can be found in literature on Social computing [37]. We further suggest thinking of home as a broader concept, including everything that might "feel like home" to users. This might involve for example distant places as "second home" and long-distance relationships, and more distant family members. At the same time, privacy of individuals must be respected — we recommend providing a more neutral mode for shared use, hiding intimate information while still reflecting the shared personality of the sharing users. In terms of accessibility, basic functionalities must be available for all users — including secondary ones such as visitors while more specific functionalities might want to be restricted (e.g., for children). We further want to sensitize readers insistently that shared use can shape information and power dynamics severely [25, 26] — therefore the topic is particularly important, as by design, smart homes can have serious effects. Paying special attention to the socio-technical dimension of domestic technology, they can be designed to empower users, contribute to make individual's mental load [17] concerning the household more visible and support users to distribute chores more equally.

4.2.3 Activities at home. Concerning *activities at homes*, smart homes can support users in creating ideal technological settings and provide scenarios to support people in establishing and sticking to habits and routines. For leisure time, this might include scenarios that promote users to immerse in different activities, providing settings that stimulate moods, such as concentration, creativity, relaxation, or physical activity. W1P3 envisioned for example to receive inspirational content for cooking: *"When you take the pot out of the drawer in the kitchen, a display could turn on with suggestions for cooking or recipes or something like that, so you're inspired to get started there"* and W3P3 thought of ideal settings to relax: *"If I take a book away, the light should get brighter. If I take the remote, the light should dim again"*. At the same time, managing a home requires inhabitants to do their chores including housekeeping, facility and technology management. W3P2 gave as example: *"I always have my shopping list in my cell phone, for example, and I always add there what I need next time"*. *"It might remind you to vacuum again or depending on whether you connect that with a robot vacuum cleaner, it might notice on its own 'okay, there's a crumb on the floor, it'll take care of it'"*, W3P4 suggested. Smart homes should contribute actively to these tasks and support users to stay on top of things to be perceived as useful. This does not only include taking over tasks and automating them, but also supporting humans cognitively to keep the overview. This provides another argument why mobile applications on personal devices should not be the dominant way to interact with smart homes. Instead, access points distributed throughout the home can make information available to all users. Crabtree et al. identified where communication media is located (ecological habitats), activity centers where media is produced and consumed, and coordinate displays where media is displayed and made available to co-residents [15]. There are some prime sites where all these areas overlap [15], and which often include dominant storing surfaces such as a work station, a notice board, or a kitchen table.

4.2.4 Cognitive resources. The aspect *cognitive resources* refers on the one side to the role of homes, to provide a shelter for residents to calm down and recover from stress and anxiety [25]. This includes to support users in performing healthy activities for example by providing scenarios as described in the previous section. Some participants expressed that technology is one source of stress in their daily life; W3P3 exclaimed *"I would go insane if I had that much technology in my apartment"* and in another workshop, W1P1 explained: *"I don't want to get push notifications all the time, I think I want to be able to set pretty clearly what I get to see and what not. I have a smartphone, so I'm already being bombarded all the time"*. Thus, smart homes could assist users in building habits and manage their technology consumption (e.g., social media) more consciously and assist users in maintaining their physical and mental health. Incorporating game design approaches in alternative smart home interfaces (e.g., juicy design elements [27], gamification [41]) can motivate individuals to use features to practice mindfulness affecting users' well-being positively [45]. On the other side, interacting

with smart homes requires some cognitive efforts of users to set everything up, maintain the network and use the devices. To allow users the interaction with their smart home devices, we suggest to incorporate tangible interaction to use technology while pursuing other activities in parallel [47]. W1P2 spoke out to design for low effort: *"I thought about whether it is perhaps absolutely necessary that they physically touch each other and thought maybe there should be some form of error tolerance, so that when I come home, for example, it doesn't always have to be in exactly the same place. Otherwise, I think it gets annoying after a while"*. Further, the administration effort must be as little as possible for devices to blend into the fabric of a home [19].

4.2.5 Visual appearance and material. With regard to the aspect *visual appearance and material*, users wish for smart home devices that blend in with the already existing interior. They appreciate varieties of (neutral) colors as offered when shopping furniture. W2P1 pointed out that social influence can shape preferences: *"I would find that really awful if it was so noticeable everywhere and everyone would see it immediately: 'Ah they have this and that device'"*. Also visual feedback elements in interfaces should strive for coziness and avoid conveying cold and rationalized emotions (e.g., using ambient notifications and emotional design elements [55, 56]). To endure everyday life, users might wish to alter the aesthetics of their home as taste and preferences change over time. Interiors of homes might be changed for example seasonally and grow with their residents — smart home devices should do the same. To design smart home devices sustainably, exchangeable covers could be available in different styles. Longevity is important for devices; W3P1 explained *"If there's something defective about it, you don't have to throw it away and it doesn't have to be repaired in a time-consuming way, but can be done quickly and it's not a big hassle."*. Furthermore, W3P2 stated: *"The surface must be practical. Let's say non-slip or adhesive, washable, the whole practical"*.

5 CONCLUSION

Envisioning smart surfaces with the aesthetics of analog ones in three co-creation workshop sessions, we derived two central themes that smart home components need to address: on the one side, they should feel like home, but at the same time, they should contribute actively to the household. To achieve that all occupants enjoy living in a smart home, it needs to be highly adaptable to different contexts and each individual's changing needs [25]. Designers should aim to design not only for comfort and convenience, but also tackle the hidden time-consuming tasks users still perform without the assistance of technology in the home. Concerning the mental load that is shouldered typically by one (female) individual in the home [17], we believe that focusing on cognitive tasks of managing household labor holds a lot of potential to facilitate everyday life and distribute chores more equally and visibly in smart homes shared by multiple users. To resolve occurring conflicts and find compromises among occupants [25], we recommend to include communication channels and social elements. At the same time, smart homes should personalize to individual users and social settings, preserve privacy for them by adapting to shared use and characteristics of groups of multiple people. Finally, a smart home should provide the scenarios that are typically described as their core tasks, enhancing occupants' comfort [25, 30]. As our participants expressed that they wish to reduce their technology consumption to relieve stress, we believe smart home systems should support them in this endeavor. With alternative interfaces to control the smart home (rather than smartphones), users might gain more freedom to interact with personal devices self-determinedly, and preserve cognitive resources for other areas in life.

We explored how interactive surfaces inspired by analog materials as user interface for smart home might look like. Regarding interaction with such surfaces, our participants expressed their visions, including ideas on feedback; next to visual elements (light effects), they described texture changes on the surface. However, as humans struggle to verbalize tactile experiences [36] our online workshop could not explore such tactile qualities in depth. Therefore, user requirements on this aspect needs to be explored in future studies, where participants are able to feel materials directly and make comparisons. Moreover, as our workshop covered only individual perspectives from households, where the other inhabitants were only considered in the thoughts of the participants present in discussion, future studies should be run with all inhabitants to take account of the social dynamics of people living together.

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