Living in a Glass House:
A Survey of Private Moments in the Home

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ABSTRACT
As advances in technology accelerate, sensors and recording devices are increasingly being integrated into homes. Although the added benefit of sensing is often clear (e.g., entertainment, security, encouraging sustainable behaviors, etc.), the home is a private and intimate place, with multiple stakeholders who may have competing priorities and tolerances for what is acceptable and useful. In an effort to develop systems that account for the needs and concerns of householders, we conducted an anonymous survey ($N = 475$) focusing on the activities and habits that people do at home that they would not want to be recorded. In this paper, we discuss those activities and where in the home they are performed, and offer suggestions for the design of UbiComp systems that rely on sensing and recording.

Author Keywords Privacy, home, sensors, sensing, capture and access, survey, self-report, Mechanical Turk, postcard.

ACM Classification Keywords H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms Human Factors.

INTRODUCTION
Sensors and recording devices are increasingly being integrated into homes. It is common for homes today to have smart thermostats, wireless smoke detectors, or home security systems. Consumer electronics such as Microsoft's Kinect and Samsung televisions already have built-in sensing, such as an RGB camera, depth sensor, or a light sensor. These types of sensors have been used for numerous applications, such as providing controller-free interaction experiences in entertainment platforms, monitoring the safety of elders in assisted living facilities, monitoring children's activities at home [4], or providing householders with detailed resource use reports for sustainability purposes [10].

However, recent work by Srinivasan et al. has shown that private activities in the home such as cooking, showering, and toileting can be inferred by eavesdropping on the wireless transmissions of data coming from off-the-shelf sensors installed in homes [11]. Furthermore, although the added benefit of sensing is often clear, the home is a private and intimate environment with multiple stakeholders (e.g., members of the household, visitors, overnight guests, and service people) who may have competing priorities and different tolerances for what is acceptable and useful—independent of concerns over eavesdroppers.

Discussions around privacy concerns over emerging technologies are not new, including Warren and Brandeis' classic article from 1890 [14] when instantaneous photographs taken by newspapers began to invade private life. Such invasion has only become more convoluted in ubiquitous computing (UbiComp) environments, which has led several researchers to investigate the intersection of privacy and technology. Some have proposed principles and guidelines to build privacy-sensitive UbiComp systems [5] or theoretical tools such as privacy risk models [3], while others have focused on identifying user tensions with privacy management [8] or attempted to understand perceptions toward recording technologies *in situ* [2,6].

While our work shares similar goals to the work above, we focus on privacy concerns around sensing and recording technologies *in the home*. Despite considerable research into many aspects of the home using ethnographic approaches or field studies of technology prototypes (e.g., [12,13]), privacy in the home has received less attention. One exception is work by Neustaedter et al. exploring privacy concerns of always-on video in the context of telecommuters working at home [7]. They created scenarios where one's privacy may be at moderate-to-extreme risk and employed privacy/awareness questionnaires. Their focus was evaluating the effectiveness of video blurring filters in balancing privacy and awareness, whereas our focus is to understand activities that people do not want recorded.

In an effort to develop systems that account for the needs and concerns of householders, we investigated the types of activities that occur in the home that could cause concern if they were to be recorded. However, studying such concerns depends on householders being willing to disclose sensitive

information about their private lives—precisely the type of information they may not want to reveal to others. To address this issue, we conducted an anonymous survey. In this paper, we present results from the survey ($N = 475$), focusing on activities and habits that people do at home that they would not want to be recorded. Our analysis focuses on the activity/task (e.g., nose picking) and location in the home (e.g., in the kitchen). Our work provides an empirical basis for privacy concerns in the home.

SURVEY

We conducted an anonymous survey using online and offline recruiting methods. We iterated the survey questions using Amazon's Mechanical Turk (MTurk), an online crowdsourcing system. We conducted 7 iterations with 114 pilot respondents before deriving the final questions and scenarios that are presented here. We compensated MTurk participants—in both the pilot and final version of the surveys—$0.10 USD per survey, but paid nothing for the offline methods due to the need to preserve anonymity.

Recruiting

We distributed the final version of the survey online through MTurk, the researchers' personal networks, and Craigslist. In addition, we distributed 150 physical postcards with nearby drop boxes and another 150 prepaid postcards returnable via U.S. Mail at local places such as coffee shops and medical center waiting rooms. MTurk workers who accepted the task were redirected to an external survey page. To protect their anonymity, no direct link was made between the worker ID and their responses. The survey was available only to U.S. residents with at least a 95% approval rating (a screening option that MTurk provides). We also posted the survey link to the volunteer section of nine U.S. cities on Craigslist.org and sent emails to our personal networks asking people to forward the link to others who were *not* students or engaged in technology-related jobs.

Survey Content

To help respondents imagine how sensors might be embedded in their homes, we provided the following scenario:

Imagine a future where you live in a smart home in which security cameras and microphones are used to protect you, the other members of your household, and your household itself. These devices would be integrated into every room in your home except for the bathroom(s).

Through our pilot testing, we found that the scenario worked best when it was neither too vague nor too specific; a vague description of sensing technologies (e.g., "a system capable of detecting activities" instead of "a camera or microphone") did not provide a frame of reference for the average respondents to understand sensor context. On the other hand, very specific scenarios (e.g., "protection of the elderly or infirm") were often too emotionally charged and thus introduced certain response bias. Therefore, we were deliberate in choosing an example ("security cameras and microphone") that was specific, less emotionally loaded, and still generally understandable to laypeople today. Respondents could only react meaningfully to questions with

respect to certain positive properties that the system was supposed to have, and thus we illustrated in the scenario that the cameras and microphones are installed for the householders' security—for their own use. We also included a statement that only the members of the household would be in control of the data. Because we offered minimal to no compensation for participating, we kept the survey brief. We asked people to describe "*at least three regular habits*" that they do at home that they would not want to have recorded. We also asked them to include *where* in the home they do the activities. Extra space was provided for anyone willing to provide additional activities. We also collected basic demographic information such as gender, age, occupation, housing structure, home ownership, and other householder members. We included a screening question at the end of the MTurk survey to filter out respondents who did not take the survey seriously [1].

Respondents

We received a total of 489 surveys, 475 of which we considered valid. We eliminated empty responses and responses from people who were under the age of 18 or lived outside of the U.S. Of the 468 respondents who provided their gender, 71.6% were female and 28.4% were male. Respondents identified themselves as students (20.9%), homemakers (11.8%), unemployed (6.3%), and having IT-related jobs (5.2%). Other occupations included attorney, writer, artist, cashier, teacher, marketer, statistician, professor, consultant, and so on. The majority of the 475 surveys came from MTurk ($n = 405$), though we note that others have found that young, female, highly educated people are overrepresented in U.S. MTurk workers [9]. An additional 30 surveys came from the physical postcards, 24 from Craigslist.org, and 16 from our personal networks.

RESULTS

We collected a total of 1433 activity descriptions that respondents reported doing in their homes that they would not want recorded. We analyzed the activities using affinity diagramming and developed a category scheme for *activity type* creating 19 high-level and 75 sub-categories. Using this category scheme, we had a total of 1533 coded activities. The activities were also analyzed based on *location* in the home. We discuss results in terms of the *types of activities* that were reported and *where in the home* the activities tend to be performed. We note that the frequencies that we report are not necessarily reflective of the *importance* or *sensitivity* of the activities, though it does indicate what was important enough for respondents to mention.

Types of Activities

The most frequently reported activities that respondents do in their homes that they would not want recorded fall into the categories of self-appearance, intimacy, cooking & eating, media use, and oral expressions. We discuss each category, include quotes to describe the activities in the respondents' own words, and discuss the influence of respondents' demographics on the types of activities that they reported.

Self-appearance. Activities in this category included walking around in underwear, partially dressed, or in the nude; the act of getting dressed & undressed; putting on makeup or lotion; and having a makeup-less face. Activities performed while partially nude or naked were frequently reported along with other activities, such as right before or after taking a shower. For example, one respondent commented,

> *"I take off my clothes in the bathroom, but then really quick nip out around the corner and toss them in the washer. It is only a foot and a half to step around the corner to the washer in the hallway. Still, I don't want anybody looking at me."*—62, F, homemaker, lives with spouse & child(ren)

Intimacy. Many respondents did not want intimate activities, including sexual activities with a partner, masturbating, and other activities such as kissing or cuddling to be recorded. A respondent explained,

> *"Having sex with my husband. We have sex in the bedroom, and since we live with children and grandchildren I would not want them to have access to recordings of that."*—56, F, legal assistant, lives with spouse & child(ren)

Cooking & Eating. Activities in this category included eating, snacking, eating sweets or junk food in particular, drinking soda, eating or drinking directly from a food or beverage carton, preparing food, and occasional binge eating. While some respondents did not want any form of eating or cooking to be recorded, it was often eating or cooking with questionable manners or in unusual places and times that was the problem. For example, respondents did not want to be recorded while eating in bed, eating in front of the computer or TV, overeating, eating with fingers, or eating ice cream at 3am. One respondent shared,

> *"If I am cooking in the kitchen and something falls on the floor, sometimes I will still use the food (though I rinse it off)."*—53, F, faculty, lives with a spouse

Media Use. The activities in this category included watching TV or movies, watching pornography, using a computer, listening to music, playing video games, and reading. Concerns focused on the possibility that other household members could find out what the respondent was watching, the ability to figure out for oneself how much time he or she was wasting by watching TV, and that passwords might be exposed if a camera could see what he or she was typing. One respondent clarified,

> *"Watching bad tv. I generally watch at least a couple hours a day of tv that I don't want people to know about because they'll mock me."*—21, F, student, lives with parents

Oral Expressions. This category included activities such as singing, having a personal conversation, talking on the phone, talking to oneself or to a pet, and crying. Respondents were concerned about recordings of conversations regarding anything from surprise birthday presents for other householders to being frustrated with other members of the family to financial plans to politics. As one explained,

Activity Type	%	Examples of sub categories
Self-appearance	22.5%	Nudity, walking in underwear, no makeup
Intimacy	18.3%	Sex, masturbating, kissing
Cooking & Eating	9.3%	Eating, snacking, binging, cooking
Media Use	8.3%	Watching TV/movies/porn, computer use
Oral Expressions	8.0%	Singing, conversation, phone calls, crying
Socially Awkward Acts	5.9%	Nose picking, scratching
Personal Hygiene	5.0%	Grooming, toileting, showering, weighing
Physical Activity	4.8%	Dancing, exercising, yoga
Sleep	4.6%	Sleeping, snoring, napping, staying up late
Home Keeping	3.4%	Being messy, cleaning, sniffing clothes
Contentious Acts	2.5%	Arguing, swearing, yelling, disciplining
Bodily Functions	1.7%	Passing gas, blowing nose, belching
Alcohol & Tobacco use	1.4%	Drinking alcohol, smoking
Unwinding	1.2%	Lounging, relaxing, killing time
Working	0.8%	Working, writing, creating artwork
Intentional sneaky acts	0.8%	Sneaking into the kitchen, hiding, stealing
Illegal behavior	0.5%	Illegal drug use
Spirituality	0.5%	Praying, reading bible
Miscellaneous	0.4%	Anything, everything

Table 1. Breakdown of activity types for 1433 activity descriptions (1533 coded activities) and examples

> *"Singing 80s songs with my cats' names substituted into the lyrics."*—29, F, consultant, lives with a spouse

Other categories. As Table 1 shows, the data that we collected can be described as a long tail. We briefly report some of the other private moments that were reported here. Several respondents did not want *Socially Awkward Acts* such as nose picking (the 5th most frequently mentioned sub-category overall) or scratching to be recorded. *Personal Hygiene* activities, such as grooming, toileting, and showering, were also considered private (e.g., *"Trimming toenails. For some reason, this should take place in the bathroom but always happens in the bedroom."*). Many respondents would not want *Physical Activity* recorded either—they explained that it *"would just feel weird"* to be recorded while dancing or doing uncommon exercises such as yoga while naked or the "air bike" abdominal exercise. Related to *Oral Expressions* discussed above, several respondents reported activities related to heated conversations and emotions—that is, *Contentious Acts*. These included arguing or fighting with one's spouse, swearing, yelling, disciplining children or pets, and making rude hand gestures. Finally, many respondents would not want *Bodily Functions* recorded, such as passing gas, sneezing, or belching (e.g., *"When I sneeze while watching tv in the living room and wipe snot off myself with a napkin."*).

Demographics in Relation to Activity Type
We observed that respondents' demographic information such as gender and household structure affected reported activity types. A chi-square test of independence was performed to examine the relation between gender and activity type, and household structure and activity type. The relationship between gender and activity type was significant, $\chi^2 (4, N = 1006) = 14.71$, $p = .005$. As shown in Table 2, male respondents were more likely to report activities in the *Intimacy* and *Media Use* categories than female respondents, while female respondents were more likely to report activities in the *Self-appearance* and *Oral Expressions* categories. The relationship between household structure and

	Gender		Household Structure	
	Male	Female	Live alone	Live with Child(ren)
# of coded activities	287	719	117	320
Self-appearance	30.0%	35.6%	32.5%	39.4%
Intimacy	32.1%	25.9%	22.2%	29.1%
Kitchen & Eating	12.2%	14.3%	14.5%	11.3%
Media Use	16.7%	10.7%	18.8%	10.6%
Oral Expressions	9.1%	13.5%	12.0%	9.7%

Table 2. Breakdown of the 5 most frequently reported activity types across gender and household structure

activity type was only marginally significant, χ^2 (4, N = 437) = 8.22, p = .084.

Locations in the Home

Some locations in the home were thought to be more private than others, which is an important consideration when deploying in-home sensing systems[†]. Though 20.3% of the activities mentioned did not report a location, of the 79.7% that did, the *bedroom* was the most frequently mentioned place (33.7% of activities that included a location). The types of activities that occur in the bedroom were often related to sexual activities, sleeping, and the act of getting dressed and undressed. *Anywhere in the home* (16.2%) was another common response and often involved family arguments and private conversations, walking around in underwear, nose picking, bodily functions, and intimacy. The *living room* (13.9%) was often mentioned with activities regarding Media Use, Physical Activity, and Oral Expressions. Of the activities that included a location, 5.2% involved *a specific path or sequence* in the home such as bedroom to bathroom, bathroom to laundry, and to and from the shower. These paths often involved activities regarding Personal Hygiene (e.g., putting clothing in the laundry before taking a shower) and Self-appearance (e.g., walking around in the nude, changing clothes).

DISCUSSION AND LIMITATIONS

The results of this study about familiar and everyday activities in the home may look obvious. However, despite their unsurprising nature, we feel that privacy concerns around sensing and recording technologies in the home have not been previously studied in detail in this context and that many of these concerns are not being accounted for in current systems. For example, Microsoft's Kinect sensor can take photos or videos of people when they are playing games. It is quite possible that shirtless game players or bystanders in the camera's field of view might accidently have their photos taken by the Kinect sensor, which could raise serious privacy concerns. Thus, we want to help designers and developers become better aware of the types of activities that their potential users consider private. It is not our intention to define privacy by generic categories of activity and location. We rather show that relatively 'safe' activities such as cooking could suddenly become a sensitive activity by subtle changes in context. Now that this work has provided a better understanding of the types of activities householders would like to keep private, our next step is to explore how particular sensing modalities (e.g.,

data processing techniques, retention periods, etc.) may affect people's privacy concerns.

CONCLUSION

In this paper, we presented the results of an anonymous survey (N = 475) of activities that householders do at home that they would *not* want to be recorded by an in-home sensing system. We discussed our results in terms of the types of activities as well as where in the home the activities tend to occur. This work has provided a better understanding of the types of private moments that occur in the home, which can help designers and developers of in-home sensing systems be more mindful of the types of activities that need to remain private.

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[*] Work done while the author was at Intel Labs Seattle.
[†] Our scenario specified that sensors were not in the bathroom.