The Autobiographical Design and Long Term Usage of an Always-On Video Recording System for the Home

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ABSTRACT

Photo and video capture is currently dominated by the use of digital cameras, often in the form of smartphones. Yet there is easily the chance that one can miss capturing a precious moment. We explored the idea of automated video recording in the home as a form of memory collection and display for families through the autobiographical design of Moments, an always-on video recording system. We iteratively designed Moments and it was used by one of the researchers and his family over a two-year period. The family found potential for the system in capturing moments that would have otherwise been forgotten in time, where they especially valued seeing 'big changes' and minute details of their life. Yet tensions existed around the family's inabilities to access specific points in time, commitment to keeping the system running, and privacy. We use these benefits and concerns to suggest future research directions for always-on video recording in the home.

Author Keywords

Photos and video; families; surveillance; memories; slow technology.

ACM Classification Keywords

H.5.2. [Information interfaces and presentation]: User Interfaces – Evaluation/methodology

INTRODUCTION

Many people capture copious amounts of photos or videos of their family members and their activities [34]. Yet there is typically a requirement that someone is present and ready to capture a desired moment [23]. This is easily challenging to do amidst the everyday busyness of life. As such, we were inspired to explore the idea of automated video capture of cherished family moments in the home. Past research has looked at the automatic recording of family moments by capturing of images based on ambient sound [23]. Life logging technologies similarly attempt to capture everyday moments using wearable cameras [48].We build

on this work by exploring the idea of always-on video recording in the home. Studies have looked at reactions to video recording in the home as a data collection tool [44]; however, we have yet to see user reactions to always-on recording when it provides them with the benefits of family memory collection. We also see a variety of research focused on always-on video that is shared live between two or more homes [28,29,35]; what we are proposing is quite different where video is recorded and accessible within a single home, not shared across homes.

Naturally, the idea of always-on video recording in home provokes many questions. While it offers potential to capture and replay significant family moments, including developmental milestones of children, celebrations, and changes in people over time, there is certainly the risk of familial privacy concerns around video surveillance. There are also a range of design questions around what locations and angles are best suited for always-on recording, when and how recorded videos should be made accessible, whether video recording should indeed be *always*-on, what moments families value most when it comes to replaying their past experiences, and what privacy concerns are evoked through always-on video recording.

We recognized that answering these questions would be difficult. They would require a large corpus of family life to be captured and then replayed, in the order of months to years, and extensive buy-in would be needed from family members in order to keep a recording system active, with the willingness to have the family's privacy at risk. This meant that traditional lab-based user studies would not suffice because they would not capture 'real' activities. Field deployments in participant homes would be ideal but problematic for such long durations of time and it would likely be difficult to get family commitment. Typically, deployments of home technologies last in the order of several weeks to one or two months because of their complexity, difficulty in running, and level of commitment from participant families [4,30]. Only in rare cases and for particular types of technology have field deployments been in the order of a year or more (e.g., [42,46]). As such, we realized we needed an alternative design and evaluation method outside of what is typically used in present-day HCI research if we were going to uncover the benefits and challenges of such a system during longitudinal usage.

Here we turned to autobiographical design, a design research method drawn from the field of computer science as a reflexive practice [1] and more commonly used in the early days of the field of CSCW as a means to deeply explore systems design research [38]. Autobiographical design involves extensive self-usage of a technology throughout its design process and is valuable for collecting longitudinal data on technology usage [38]. It has been shown to be particularly valuable in situations where it is difficult to deploy technologies in real situations given their frailty and incorporation of ubiquitous technologies [37,38]. It is also useful in situations where researchers want to "put themselves in harm's way" first with a potentially risky system before knowing how it should be designed and presented to other users more broadly [37,38]. In this way, it is a test case to understand what is important in the design, what should be refined, and what should be left out. The goal of autobiographical design is certainly not to generalize usage behavior to broader populations; instead, it is meant as a means to deeply understand a design area to suggest research direction [37,38].

Our research involved designing an always-on video recording system called Moments and using it over a period of two years. Our design draws from slow technology design principles [20,42] as a means to create anticipation and reflection around the reveal of past family memories. At the 21-month mark of usage, we had a second researcher, independent from the family, conduct interviews and design activities with the family members to understand the effect of Moments on the family's life. Our paper describes and reflects on this long-term usage to reveal key themes related to the value of media content and aspects of presence, commitment, and privacy with video recording systems. We use these lessons to step back and explore the broader implications from our work for the design of always-on video recording systems in home environments.

RELATED WORK

Photo and Video Capture and Sharing
Traditionally, families and friends shared photos with each other in a collocated setting using printed photographs [9,34]. This social act was highly desirable and people's preferred mode of viewing [9,17] as it allowed family members and friends to reminisce and tell stories about their experiences [13,17]. As digital photos and videos became widespread, the amount of work needed to manage them became large [31]. Given the popularity of collocated photo sharing, a variety of prototype systems have been designed to support such practices around digital media. For example, these have focused on photo viewing and reminiscing around a digital table [24,49] and the design of domestic objects to support collective memory amongst family members [51], conversation, and reminiscing [5].

There have also been systems designed with an emphasis on automated or ubiquitous capture of video, similar to Moments. The Other Brother [23] captured unplanned or spontaneous photos in the home based on ambient sound. Studies found that family members appreciated the capture of surprising moments [23]. Initially family members had privacy concerns, but, over time, they noticed the recording device much less. TIMELINE provided the recording and rapid review of video from multiple workspaces [40]. Participants could watch each other work in real time, or see recorded footage from earlier. SenseCam was designed as a lifelogging camera to capture images throughout one's day [7,8] and has been shown to allow people to connect to their past as well as aid memory during challenging health situations, e.g., Alzheimer's disease [7,26,48].

Slow Technology
Researchers have recognized that technologies designed for settings outside of the workplace need to move beyond efficiency to other forms of meaning and connection where people might draw different understandings from their media or data and its consumption [20]. To this end, slow technologies aim to create a more meaningful connection between people and computational artifacts through designs that take time for users to learn how they work and why they work in a particular way [20,42]. For example, GoSlow was a slow technology for mobile devices that periodically prompted users to reflect on their mood [10]. Postulater let users share photos or videos with family by sending media to a specific date and time in the future [21,22]. A field study showed that these features created valuable reflection [22]. The PhotoBox was a slow technology that randomly printed out Flickr photos for household members as a means to reconnect them to their past [42]. This created additional interest in users' photo archives [42]. We build on these ideas to explore how principles from slow technology design might be used with always-on video recording to create user reflection.

Always-On Communication Systems
Always-on video for communication has been explored in domestic settings as a means to connect multiple homes together. The VideoProbe [12,27] shared still images between homes based on user movement. Users enjoyed capturing humorous moments and being playful, but sometimes had privacy concerns [12]. RoomLink focused on shared audio between two household; however, focus groups revealed privacy concerns over streamed audio [25]. The Family Window connected two homes and provided 'time shifted' video that could be recorded and played back. Participants liked the idea of having the option of recording events since it meant they would not likely miss special moments [28]. Family Portals connected three households together with always-on video [29]. Users valued the sense of connection, however, there was increased privacy risk by having more people connected [29]. Our work is similar, however, we look at only recorded video rather than live video streaming between homes.

Surveillance and Video Recording
Ubiquitous surveillance involves the "unilateral collection of data on people with sensors embedded in their everyday

environment" [44]. A day reconstruction study on video recording in environments such as offices, malls, and public spaces found that people were concerned with notification and consent to be recorded, improper access to video, and unauthorized use [39]. Using a similar method, Massimi et al. [33] found that people use visual cues in their environment to determine if they are being surveilled (e.g., the presence of cameras). O'Donnell et al. [41] found that surveillance is more accepted when performed by a group with whom one identifies. A survey by Choe et al. [11] that asked people to speculate about their reactions to ubiquitous recording in their home found that they were concerned about being recorded when partially clothed or during intimate or socially awkward acts [11]. They were also concerned about audio being captured, including talking to oneself, child rearing, and arguments [11].

As can be seen, most studies of ubiquitous video recording focus on speculations of usage with few exploring actual usage and reactions to recording in the moment. A notable exception is the Helsinki Privacy Experiment, a study of ubiquitous surveillance *within* families' homes over a period of six months [44]. The idea was to explore a 'worst case scenario' where a large amount of data would be logged without any particular benefit to users. Some surveillees grew accustomed to having their lives logged, while others grew increasingly concerned or changed their behaviors to reflect the fact that their activities were being recorded and logged. The most disturbing sensors to participants were video and audio recording along with Internet activity logging. Our research builds on this study by more deeply exploring video recording in the home, in particular, when the family has potential to receive benefits from the recorded footage (e.g., family memory collection).

The Human Speechome Project (HSP) is also similar to our study of Moments. In the HSP, video cameras continuously capture a single home in an effort to understand and map children's speech development patterns [47,52]. While also focused on recording *one* family's activities, the HSP has not studied the family's reactions to continuous capture.

AUTOBIOGRAPHICAL DESIGN AS A METHOD
Our research draws from autobiographical design as a design research method. Autobiographical design is "design research drawn from extensive, genuine use by those creating or building the system" [38]. It draws its roots from practices in the 1980s by computer scientists who designed for themselves as a *reflexive user* where they would imagine themselves as future users [1]. In the early days of the field of CSCW, media space researchers used a similar self-usage approach to design and study their systems [3,15,32]. Since then, it has been periodically used and published as a design research technique (e.g., [16] in 1996, [18] in 2006, [28] in 2010, [14] in 2016)). Yet what happens often is that researchers use the method but are hesitant to publish their results from it because of potentially negative reactions from peer reviewers [38].

Autobiographical design is similar to design requirements elicitation methods such as ethnography and technology probes, yet differs in observations and understanding of usage, which are tied with an initial period of design iteration [37]. Usage is then tracked long term over periods of months to years to provide detailed longitudinal data situated in aspects of 'real life' [37]. HCI and CSCW expert researchers who have used the method described it being a valuable design research method for early design when little is known about a design space and when it is difficult to deploy a technology to external users or where it may not make sense to do so [38]. However, they cautioned that autobiographical design needs to ensure its own sense of rigor as is the case with all research methods in the field of HCI [38]. Rigor for autobiographical design means careful and critical reflection on one's work including, *"an extensive period of genuine, intensive use, measured in months or years; surprises in usage that lead researchers to rethink or develop initial design conceptions; improvements to design driven by specific, documented incidents of use; and careful articulation of the impact of design decisions on experiential qualities of the system."* [38]

By following these tenets, autobiographical design supports fast tinkering with an idea, reveals 'big effects' from usage, and provides detailed and experiential understanding, not often available from other research methods [38]. Of course, autobiographical design does not produce generalizable results, and nor should this be expected [38]. In the subsequent sections, we describe how we employed an autobiographical design approach to create and study always-on video recording in the home.

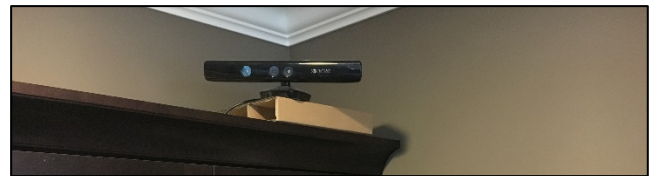**Figure 1: The Moments camera near the roof of the kitchen.**

Figure 2: A Moments iPad on the kitchen counter.

THE DESIGN OF MOMENTS
Moments is an always-on video recording system with an interface designed to help families revisit memories. The system is designed to be used within the home. A Kinect camera is placed in one location and connected to a computer that records video continuously (Figure 1). A web

application runs on a tablet and has access to play back the recorded video (Figure 2, bottom right), with constraints that are described in subsequent sections. The goal is to help families collect and reflect on past moments and experiences that took place in certain areas of the home.

Design Need and Iteration

Moments was designed to capture everyday spontaneous moments that occurred within a family's home. Due to the study being longitudinal and privacy intrusive, the research started with one of the author's family containing himself, his wife, and his three young children (aged 1, 6, and 8 at the onset of the project). The idea was to be able to capture the growth and development of each family member, especially the kids in the family, as well as the 'special moments' that might occur in home. These special moments might include, for example, a child's first steps or family celebrations. There was a particular interest in the changes that might occur within these moments over a long period of time, for example, seeing a pattern of who sits down to eat together at mealtimes and how this might change. Many of these moments were either missed or difficult to capture. That is why the researcher thought about a more automated approach for such capture.

Over a period of four months, an undergraduate research designer iteratively created Moments through a series of brainstorming, sketching, and prototyping activities, in consultation with the researcher. During this time, Moments was placed in the researcher's home in a home office and recreation room to explore the design ideas as they were developing. This represented a period of 'fast tinkering' with the design, which is common in autobiographical design and one of the benefits of the method [38]. After four months, the design reached a stable point where the researcher and designer felt the system met the primary needs of the family. Development ceased and the family began using Moments more permanently in the main living space of their home, a kitchen/living room.

Usage Constraints

As we designed and built Moments we recognized that we wanted to purposely include a number of usage constraints in an effort to make the system more focused on family moments and less on surveillance. Our ideas were inspired by slow technology designs where notions of time and relevance can be brought to the surface by allowing a design to slowly reveal itself, its contents, and its value to the user [20,42]. For example, content from the past could be revealed to the user at particular moments in time in an effort to make a past moment more memorable or valuable than it might otherwise be if it was more easily accessible [22,42]. Existing systems such as the PhotoBox [42] and Postulater [21,22] used this technique to bring forward photographs from the past to the user in present day where the technique created valuable user anticipation and

reflection; we extended this idea to video recording.

Location

First, in order to watch recorded video, the user must be located in close proximity to the capturing camera. For example, Figure 3 shows Moments displaying video on an iPad located on a kitchen counter. Directly above it is the recording camera. Clicking on a 'settings' icon on the Moments display causes a calendar to appear that family members can use to select a date that they would like to review for that camera. When a date is picked, video plays for that day. Thus, family members can set the iPad on the counter (with the screen set to permanently stay on) and video will be shown of the selected day continuously. In this way, it can act as a glanceable display into the family's past. The idea of glanceable displays in the home builds on prior work on digital family calendars [36] and messaging systems [43] which show that families find value in being able to walk by and glance at content on a display with ease. Previous research also suggests that playing the video back in the same location it was recorded in can help create an emotional connection to the video [45].
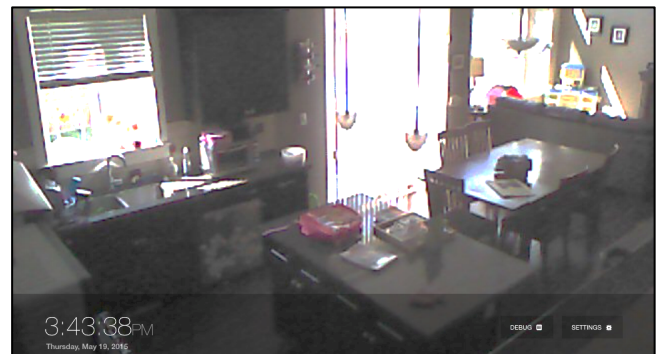

Figure 3: Moments showing video from one year earlier.

Timing

We also constrained the timing of the video that could be replayed. Video is only ever played from the selected day at the present time. Thus, when selecting video to play on a display, if one were to select yesterday as a date, and it was presently 1:00 pm, the device would play video from yesterday at 1:00 pm. For example, if a person wants to see video of children opening up presents on Christmas morning, she/he would need to think about what time of day that occurred at, and then wait until the next day to see it, if the time had already passed today. The intention was to use the time delay to generate anticipation much the same way that slow technologies have been successful in creating anticipation around the reveal of time-delayed photographs [21,22,42]. We also felt that by bounding video replay by three elements—time, date, and location—we could ease the burden that might come with having a large video archive and being unsure of what to review.

This type of viewing contrasts nearly every present day photo or video-sharing application where usage includes letting people easily access recorded videos and replay

them at any point in time. Despite this ease-of-access, researchers have, somewhat ironically, found that people do not often view their saved videos/photos once they are placed in an archive [17]; thus, in some ways, we wanted to see the effect of an 'opposite' style of design. We also recognized that by limiting playback, family members would not be able to replay any moment at any point in time, as well as re-watch moments in short succession. This might be more akin to scrubbing recorded video from surveillance systems, which was not our intended use of Moments. Of course, there are many ways to design a system such that it does not feel and act like a video surveillance system. We chose but one route that seemed promising and reflected the desire to create anticipation with the revealing of past moments.

Audio

Moments does not record audio due to privacy concerns and the desire to not resurface 'bad' memories (e.g., arguments) from the past, which might be more easily noticed with audio. Previous research on always-on video media spaces in the home has found the transmission of audio to be more privacy-invasive than video [28,29]. Prior research has also shown large concerns over audio recording and streaming [11,25]. By capturing audio, we would be more likely to record family arguments or negative conversations about other people, which might be much less desirable. On the other hand, video of such events would likely appear somewhat mundane. We also did not want to alter conversations in the home, which was found by researchers studying audio recording [44].

Implementation

Moments works with two applications. The first runs on a Mac mini connected to a Microsoft Kinect camera and continuously polls the camera for images at a resolution of 640 x 480. Images are stored in a database running on a local server computer within the home. Thus, there is no concern over access to the images from outside of the home. We deliberately chose low-resolution images to reduce storage consumption. Video is also captured at a low rate of up to 5 frames per second (fps). Computer vision techniques are used to detect how many people are present in the room. If nobody is present, we captured video at a rate of 1 fps in order to capture changes in the ambiance of the room (e.g., lighting changes). The user interface to replay video is implemented as a web application that can run on any tablet, computer, or smartphone device when connected to the home's intranet. When a date is selected, images are retrieved from the database and concatenated together to playback video from the time period. Video continues to play as long as the web page is open.

EVALUATION METHOD

Moments was used by the researcher and his family for a period of two years. Throughout this time, the researcher recorded periodic confessional videos of himself and his children that described their usage of Moments and their thoughts about the system. These videos represented the thoughts and reflections from a trained researcher in HCI. This brings the added value of having a researcher as a participant where the researcher is trained to observe, critique, and reflect on the family's usage with extensive knowledge of the related literature and continuous access to observe the home environment and see nearly all of the effects of the technology. Such 'all day, everyday' observations are not usually possible in field studies.

We wanted to augment this data and understand the family's usage from an external perspective as well as bring additional rigor to the analysis by having a second researcher, independent from the family, perform data collection and analysis. Our goal was to have an unbiased, third-party researcher understand the family's experience and analyze, describe, and document it. This person was brought on to the project and she conducted semi-structured interviews with family members at the 20-month mark of usage. The confessional videos were used as an entry point to think about how the interviews should be structured and what focal points would be interesting to explore.

Interviews

Interviews with the two parents focused on topics such as usage patterns, views of the recorded video, location of the camera and privacy. For example, the invited researcher asked, "When do you most often look at Moments?", "What do you look for?", "Tell me about the most surprising usage you found for Moments". The two oldest children (aged 7 and 9 at the time) performed a design activity that involved drawing Moments, how they thought it worked, and what they would like to add to it, if anything. For example, the invited researcher asked, "Can you draw what you would like to add to the Moments system?" After the activity, the children were interviewed about their drawing and thoughts on Moments. The interview focused around their knowledge of the system, details of what they saw interesting in the system, and possible privacy concerns. For example, they were asked, "Can you tell me about a time you tried to look at the display very closely to see what was happening back then?" The third child (2-years old) was not interviewed.

Data Collection and Analysis

Interviews were audio-recorded and transcribed for data analysis purposes. The independent researcher performed open coding on the data to draw out the important findings and then axial coding to group them into categories. Selective coding was used to draw out and summarize the key findings into themes. These are discussed in the following sections and relate to aspects of commitment, screen attention, reflecting on moments, time constraints, and privacy. Throughout our results, we refer to the family members as the father (researcher), mother, oldest son (age 9), the daughter (age 7), and youngest son (age 2).

GENERAL USAGE

After the initial four months of Moments' design and development, it was setup within the family's home in the

kitchen on the main floor. A Kinect camera was placed on top of the cupboard in the corner of the kitchen. Figure 1 shows the camera's placement and Figure 3 shows the view from the camera. Both parents wanted to capture the family's everyday comings and goings, activities around the dining room table, and play that might occur in the adjacent living room. In contrast, placement of the camera on a kitchen counter may cause it to change viewpoints fairly frequently or be blocked by items. On the counter below the camera, the father placed an iPad, which was meant to continuously show Moments on a selected day (Figure 2). The goal was to make the video viewable at-a-glance when they walked by, such that they might be drawn into looking at it more closely if something interesting appeared. This location was never changed during the family's usage, which reflects the value of the location and its mapping to the family's needs. Family members described glancing at the Moments display when they were in the kitchen area getting dishes or food, or while on their way to the garage. The related literature on photo sharing suggests that family members might move the design to a area like the kitchen table for shared viewing [24,49]; however, this never happened with their use of Moments.

For the first year, Moments was set to show yesterday by default. Sometimes family members would change the date (described later), but this was infrequent. After the family had used Moments for a full year, the design was modified so that by default it showed video from exactly one year before. This created a straightforward way of knowing what Moments was displaying; it was always exactly one year ago. This display configuration continued to the end of their usage when the equipment was removed for use in other projects. Throughout the remainder of the results, we describe the way in which the family used Moments and their reactions to the system.

SEEING BIG CHANGES (OR A LACK OF)
The family was most often drawn into looking at the Moments display when they would glance at it and see 'big' changes in the video compared to present day. For example, they noticed dramatic appearance changes such as someone having long hair vs. short hair, the changing ways in which a toddler sat at the kitchen table (in a high chair vs. a regular chair), as well as large changes in clothing styles, such as might occur on a special occasion.

"We notice when somebody has super long hair compared to super short hair." –Father

"There are times that I pass it and I'll be holding [my youngest son] and I yell for [my oldest son], or [my husband], or [my daughter] to come and see, 'Look how small he was!' He is the one you can tell the greatest difference in because he was a baby and he was in my arms and now he's a toddler running around." –Mother

Family members were also drawn in to looking more closely at Moments when there was a *lack* of big changes.

For example, a family member might notice that someone was wearing the same shirt today as they did a year ago, recognizing that the shirt was now likely 'getting old.'

Family members repeatedly talked about times when they noticed guests in their home on the Moments display. Seeing only their immediate family members on the display was fairly typical, yet seeing an extended family member or friend on Moments was rare and so it tended to spark curiosity. This curiosity led one or more family members to congregate around the corner of the kitchen and look more closely at the display to inspect who was there and ponder over the reasoning. This was typically a conversation-starter amongst family members if multiple people were around.

"I think the most surprising would probably be when you see somebody on there that's not a part of the house. And you have to remember back to ... like I'll see my mom on there and I'll be like, 'Hey! My mom was visiting us last year at this time? What was she doing out here?'" –Mother

THE IMPORTANCE OF 'THE DETAILS'
The entire family was keen to be able to see past moments that were tied to birthdays and special seasonal celebrations, such as Christmas or Easter. For the first few months of usage (December through March), because the system had not been recording for a very long time, when the family purposely selected dates to look at, they often focused around the recent Christmas.

As time progressed, family members would notice the replay of birthdays, holidays, and other special celebrations that had occurred in the home. Yet what was surprising was *exactly what* they found interesting in those moments. Rather than enjoying the re-creation of the event per se, both parents and the children found it interesting to look at the details of what was going on. Thus, the value of the video was not in seeing a replay of the overall event. Instead, value was found in knowing the specific details of the day, regardless of how mundane they might seem. For example, the parents liked to see what item was prepared for a meal, what show was playing in the background on the television, what shirt each person was wearing, how the house was decorated, or what time of day people were awake and eating breakfast. In addition, family members said that the preparation for important celebrations was interesting to see. Normally this was not something they would capture on photo or video.

"Say it was Christmas and I looked back at last year's Christmas…What was cool is, each year we change our tree. Change where our tree is. The stockings are usually different. When we set the decorations you can see it on Moments, which is really cool." –Oldest Son

The father distinguished such usage of Moments from the way that they routinely used photos and videos within the family. With Moments, memories were about a broader, more detailed view of life.

"It's more about a way to capture this higher level sense of our existence, whereas I think with a photo or a video, you're catching a very specific instance of your life. This is not that. It's about, what was life like for me at that point in time?... it's all these mundane things that we do." –Father

Although the time constraints of the system added a sentimental value to it, they also caused burdens in terms of its usage. Sometimes the mother and father wanted to see a special moment but they did not know what day or time it happened at. Instead, they remembered details of the activity and their feelings associated with it. This led to less targeted usage with the system (e.g., looking at a specific moment of interest) than the parents had anticipated.

"You have to know exactly what time the memory happened in order to go back and use it....So, that's why I think it's less useful for me because even on birthdays and stuff, unless I know what time we had the cake, I have to keep periodically checking it every couple hours in order to go back and get that memory." –Mother

THE PURPOSEFUL CREATIONS OF MOMENTS
While much of the moments that the system captured were spontaneous, there were instances when family members would do certain actions for the sole purpose of Moments capturing them. For example, throughout the first few weeks of usage, while the novelty of the system was still in effect, the children and father would occasionally perform silly actions such as waving at the camera or performing dance moves. The hope was that they would see them again at some point in the future. The children, in particular, liked seeing themselves on the screen.

"Me and [my sister] would usually dance. We'd dance in front of it and then go see what was happening when we'd hide behind the couch and just pop up." –Oldest Son

While this behavior mostly happened during the design's early usage, the behavior periodically resurfaced when guests were over and Moments was explained to them.

On another occasion, Moments was used by the father to purposely capture information for his children, to be seen at a later point in time. The father was going out-of-town to a conference and so he created a scavenger hunt for his children to do while he was gone. The father recorded himself in front of the camera making a particular gesture with his arms. He recorded the date and time of this event on a piece of paper representing the clue. Then, when he was out-of-town and the children were doing the scavenger hunt, they had to view the associated video in order to see what their father had done as part of the clue. This required them to wait until the next day at just the right time to see the father's visual message.

Reviewing these purposefully-created moments was easy in the above instance because it was carefully planned. However, the difficulty in knowing when past events occurred meant that the humorous clips that the children recorded rarely resurfaced because they did not carry a significant date with them that was easily remembered.

LONG TERM PRESENCE AND COMMITMENT
Moments was designed to provide automated capture in an almost unobtrusive form. That is, it was expected that video would simply be recording without the requirement for intervention, or, perhaps, even knowing that the system was recording. Yet usage was far from this ideal. Instead, the system had somewhat of a continuous presence in the home. For example, the father described Moments as a 'friend that was always around.' The computer made a soft humming sound as it processed and recorded video, which meant that it was easy to notice it was running. The father also described somewhat of a continuous sense in his head that Moments was running and needed to be attended to in order to ensure it stayed running. These thoughts came up often when he was near the system. For example, the father talked about always ensuring the cupboard door near Moments was closed because if it was left open, it would partially obscure the camera's view.

"If something is capturing you all the time, you develop this sense that you need to help it capture you and you're not going to block its view. Now I'm its friend and I have to help it out and make sure it can see all the time." –Father

The children liked to routinely use the Moments iPad to play video games. This occurred in the morning before school and during intermittent periods of time after school. The challenge was that every time the iPad was used to play games, it had to be returned to displaying Moments when the play was done. The children were initially told to do so by the father and then it eventually became a habit. Again, this represents act of commitment to ensure the technology was running.

The mother talked about easily noticing when Moments was not working, e.g., the video display was blank. During these times, she felt compelled to tell her husband that it was not working, such that he could either restart it or find out the problem. This was ongoing and, again, represents a sense of commitment to the technology.

Over time, both the parents and children grew accustomed to the presence of Moments. This helped entrench the feeling that it was 'part of' the family and a representation of their life together for the father. He described his desire for the presence of the system and his commitment to it to persist longer term such that it could then act as a type of family heirloom that could be passed on from generation to generation. This was despite the work needed in order to ensure it was always running and recording the family.

"It is useful as a family heirloom, which is weird because I never expected it to be like that...[With Moments] it's just this comforting thing that you see on the counter." –Father

PRIVACY
Family members had several concerns when it came to

privacy. Initially, the father was concerned that he would forget that the camera was recording and be recorded partially clothed (e.g., first thing in the morning). Yet this concern went away with time as the idea that his life was being captured became 'routine'. The mother had concerns about being recorded while breastfeeding her baby. Her concern was not with being partially clothed though. Instead, she sometimes worried that the video might resurface when guests were around and they would have issues with 'breastfeeding in public.' Thus, while breastfeeding her baby, it felt similar to breastfeeding in a public place. In this way, she said her home was momentarily transformed from being a private dwelling to one where she had to concern herself with public perceptions of breastfeeding and whether others would be offended. Despite the concerns, this type of video recording never happened to appear when guests visited, yet the potential for such an instance to occur still existed.

"I think the only thing is when I nurse [my youngest son]. Because it happens wherever, whenever. So there's no real time for it. I don't really care, but then I wonder if people are over at the house…" –Mother

In addition, the mother periodically worried about her husband's perceptions of her as a stay-at-home mother. She was concerned that her husband might look at Moments and see what she was doing during the day, and judge her as 'not doing enough.' She also worried that sometimes bad memories might be captured of her or her husband getting upset with their children for misbehavior.

The daughter (age 7) described Moments in a way that was similar to a surveillance system (e.g., cameras watching you) though she was not bothered by it and enjoyed that she could "*see people easier*." The son (age 10) did not have any concerns about privacy when asked.

Given their privacy concerns, both parents talked about how Moments caused them to create a mental representation of what was a 'private zone' in their home. By private zone, they referred to places in the living room and kitchen (or adjoining rooms) that could not be seen on-camera. They said that, because Moments' had a fixed location, it was easy to create this mental model.

"I know the privacy zones… And I know if I go further this way into the living room, then it's more blurry." –Mother

"I think because of the fixed viewpoint, I have a really good sense of what is on camera and what isn't. Because it never changes…I guess I'm always in my head remembering what that zone of the house is." –Father

Both parents were concerned about guests to the home and whether they would be comfortable with Moments capturing them. Guests included periodic visits from friends and stays of several days by grandparents. Both parents said that they routinely told the guests about the system as part of conversation and, initially, the guests appeared uncomfortable where the guests described the system in terms of surveillance. This is likely because they did not receive any benefit from it. Guests also did not have the advantage of knowing what regions were visible on camera given their limited usage. Thus, unlike the family members, they were not able to develop a mental model of the system longer term. Despite these concerns, the parents said that, later in their visit, guests looked as though they had 'eased' into having Moments going or likely had forgotten about it.

When each family member was asked whether there was a time that they wanted to delete footage, their answers were all negative. They said they usually forgot that Moments was recording so they would not know what was recorded.

"I honestly can't think of a moment that I would want deleted because I sometimes forget it's recording. So, I wouldn't know unless I went through every day, every hour, if there was something I would want deleted." – Mother

The father said that there were some recorded moments that he did not want his children to see at present time, For example, he noted that Moments had recorded the parents placing Christmas presents from Santa Claus under their tree on Christmas Eve and, if the kids saw this footage, it would ruin the idea that Santa Claus was real. Seeing the video at a later point in time once the children had learned about the true nature of Santa Claus would be fine.

DISCUSSION

Our paper explored the autobiographical design of an always-on video recording system for the home. Given our focus on the researcher's family, like other autobiographical design studies [37], our goal is not to generalize the usage of the system to other families. Instead, we now focus on several key takeaways from the family's usage that suggest further design investigations in this research space and raise important research questions.

What is Valuable to Record?

First, we found that Moments challenged our assumptions of what might be considered valuable to record in the home. This raises design questions about what is important to capture in video recording systems and what family members may find valuable to see during playback. As expected, the family did indeed value seeing changes over time. Yet what was surprising was the level of detail they valued seeing and how such details pertained to everyday mundane things. This is because the details became forgotten and prompted the family, in a quizzical fashion, to think about and question their past. These findings are similar to the mundane details that prior work has found to be valuable when sharing always-on video between homes [28]. Now we see that such information is also valuable within large collections of recorded video, when one might seemingly expect a person to focus only on 'big' life moments and changes, given the sheer volume of data.

The challenge is that it could be difficult to know what people are interested in seeing a priori, which speaks to the

value of always-on video recording. By 'capturing everything,' one has the option and the ability to gather whatever sort of details they might find interesting to review after the fact. However, capturing everything may not always be an option, given the pragmatic realities of long-term capture with always-on video recording (e.g., disk storage). Thus, determining what is worthy of capture ahead of time would certainly be useful. The most interesting moments for the family tended to revolve around situations where more than one person was present, including everyday situations as well as holidays and celebrations, as well as points in time where a non-family member was present. These types of situations are relatively straightforward to detect with computer vision techniques (e.g., counting people). This suggests value in future design research that explores the automatic capture and replay of such situations. However, family members also valued seeing the 'unremarkable stuff' that might be more difficult for a machine to detect. This raises the question of whether or not technology could understand what might be thought of as 'unremarkable' or mundane, in order to periodically capture and resurface it. This design tension should be explored.

Our study also revealed a desire to specifically tie together time periods through a form of asynchronous communication where family members would purposely do something in front of the camera for their future selves. This is intriguing as we have yet to see designs for families that purposely allow them to do this in the home. Research prototypes have supported the random reveal of past media content [42], but none that we know of have allowed one to specify a future point in time for content to 'reveal' itself. Designs have done this for mobile device usage [21,22]; our research suggests the expansion and exploration of these ideas for situated displays in the home. Research should explore how this type of system might alter the future of family narratives and collective memories associated with events. For example, there is the chance that 'bad memories' resurface and how designs deal with such situations remains an open question. Should an individual be allowed to remove such data? And, if so, how, when, and by whom since the interpretation of memories may be different for different family members.

Tensions with Slow Reveal
Second, our study reveals new ideas around the design and long-term use of slow technologies. Past research on slow technologies shows that users can face a tension between a lack of control over the reveal of content and the enjoyment they receive from its slow and random reveal [42]. Yet in past research, users have had other options for accessing their media content (e.g., an existing communication system [20], a Flickr archive [42]) outside of the slow technology, if they wanted. In our case, users could *only* access their content through a slow technology. This created frustration because users had control over what was viewed, but they did not necessarily know where to look to see content they

were interested in. They could also not look at other systems to see their content; they were forced to have Moments reveal it to them. This raises design questions around what amount of control a slow technology should provide users. Should a slow technology only ever provide content in a way that reveals itself slowly over time? Or should there be hybrid approaches where content is also made more accessible to users? What is the appropriate level of control and access? Will additional levels of control take away from the benefits of slow reveal?

Given these questions, we see benefits in exploring always-on video recording systems that might remind people of when particular events of significance occurred (e.g., birthday parties or celebrations) to provide a greater sense of control, while still allowing the system to reveal content to family members. For example, systems could provide visual indicators in a calendar of how many people were present at particular moments in each day; a large number of people might mean it was a family gathering. Designers may also want to explore ways to allow family members to flag or highlight days of importance shortly after interesting moments occurred by, for example, interacting with a display to 'tag' days or times. In both of these situations, family members might still be able to gain the benefit of anticipation by waiting for a time of day to play, yet now they would have a stronger sense of what days to look at.

We also recognize that family members may want to purposely block the availability of certain moments and restrict access to them. This may be permanently or for shorter durations of time. For example, the parents wanted to hide videos of them acting as Santa Claus until a later point in time. This raises questions around how designers may want to allow users to include or exclude content from appearing where it may be available at different times (e.g., when children have reached a certain age) and not others. Again, it raises the question, who should have control over such access and settings?

Commitment over Long Periods of Time
Third, we recognize that there are important considerations to be made about the level of commitment that an always-on video recording system creates. Moments created an ongoing sense of presence in the home for itself and with this presence came the creation of work and commitment by family members. Even though the system was meant to be autonomous and passive in its recording of the family's life, it still required work. Certainly some of the work came from the fact that the system was still a research prototype. Yet it is also likely the case that if always-on video recording systems are placed in homes more broadly, the users will not be as technically proficient as the family members who used Moments (e.g., the researcher) or perhaps as committed. Thus, even in a possible 'best case' (the researcher's family using his own design), commitment is a major concern. Systems like Moments would likely create additional work for family members just like it did

for the researcher's family.

Such ideas need to be thought through if designers are to consider the broader exploration of always-on video recording. Always-on system in some ways means that it must be always thought about, or frequently attended to. Unlike past slow technology research where designs could be hidden or not worried about, if desired [42] The pragmatic challenges of large amounts of data from always-on recording means that such systems can be difficult to forget about. Cloud-based servers may provide a storage solution, but they pose the risk of having one's data stored outside of the home. This raises design questions around how such systems could be created to relieve user commitment while still ensuring usage continues long term. How does one design for device placement such that 'good' views of family life are always available? How can technical issues be attended to by users in a manner that requires as little attention and commitment as possible?

Privacy
Lastly, there are questions and challenges around privacy. Always-on video recording caused the parents to create a mental representation of what was on camera in their home where fixed camera locations made it easy to develop such mental models. This is similar to how location was critical for always-on video sharing between homes in prior work [35] only with Moments video is recorded and not ephemeral. With video streaming between homes, privacy intrusive moments may come and go quickly because they are streamed and not recorded.

Guests did not have the advantage of easily knowing what was on or off camera and nor did they receive benefit from the system, unless it was valuable to them that they be recorded as part of a family moment. This raises questions around how guests can be easily told about recording devices or have recording zones presented to them in an understandable manner. The use of an always-on recording system can become unremarkable to family members over long periods of time, and, after prolonged use, they may not want the constant reminder that the system is recording, despite the value of the feature for guests. How can designs create a balance between warning people about always-on recording and not being obtrusive in the presentation of this information? Design suggestions from the media space literature across the years [6] present some possibilities from workplace settings (e.g., feedback displays), however, this requires testing and exploration in home contexts since domestic life can be much different than work.

We also found interesting issues arise around gender politics and what is acceptable to be captured and replayed, and the various views people may have about it. This arose around topics such as women's roles in domestic life. Such issues did not come up in past research on always-on video streaming between homes [28,29,35] or ubiquitous capture of domestic life [11,44]. Again it raises questions around who should have access to the recorded video and at what points in time. Even within a single household, it may not be the case that family members want everyone in the home to be able to see everything, all the time. Should a person only be allowed to see the moments that they were apart of? Or should they only be allowed to watch video of others if everyone in the video is present and watching together? would these ideas be seen as being overly restrictive? One challenge is that people and their perceptions change over time. For example, young children may be comfortable in having video recorded, but this is not to say they will share the same views when they are teenagers or adults and videos of their past are resurfaced. This raises further questions around control and access.

Limitations
Our study is limited in that we did not explore the reactions of guests to the system. Future work should certainly explore this broader set of stakeholders for always-on video recording. At this stage, we can only speculate about their reactions, based on comments from the primary users of Moments. Currently the system is not running at the home anymore since Moments was required for another project. We used autographical design as a research method to accomplish a long-term study in the field for two years. A study of this length is very rare within the field of HCI and interaction design. While utilizing external families as part of a deployment would have been valuable, we felt it was most appropriate to test this type of technology on ourselves first to understand the likely impact before trying out similar design ideas with other families. This was because of the potential privacy risks associated with always-on video recording. This allowed us to understand the risks that might occur with such systems so they can be specifically designed for before future studies, or future studies could directly watch for them in order to circumvent negative situations.

CONCLUSION
We studied the design and use of an always-on video recording system called Moments. Through this process, we identified several themes of behaviours and routines around one family's long-term usage of the system. On the positive side, the family was able to gain a valued perspective on their life and be reminded of their past experiences, sometimes in great detail. However, the design of Moments raised important design questions around how past moments should be made accessible while still creating anticipation; and, how always-on video recording systems can be designed such that they do not create new commitments around their maintenance and ongoing care as well as privacy concerns. This raises important design questions for future research to explore that build on our autobiographical design experiences.

ACKNOWLEDGMENT

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