Digital Family Portrait Field Trial: Support for Aging in Place

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ABSTRACT
A growing social problem in the U.S., and elsewhere, is enabling older adults to continue living independently, as opposed to moving to an institutional care setting. One key part of this complex problem is providing awareness of senior adults' day-to-day activities, promoting "peace of mind" for extended family members. The Digital Family Portrait (DFP) is one approach to providing peace of mind that has shown promise. To date, research on the DFP has been limited to wizard-of-oz based experiments over short periods of time. This paper describes a DFP field trial in which a private home was instrumented with sensors rather than relying on input from wizard-of-oz technology. This field trial was conducted over a period of one year between an aging parent living alone in her own home and her adult child living 50 miles distant.

From this field trial we find that even though there was no critical reason for the adult child to be concerned about his mother, all involved parties found utility in the presence of the DFP, even those family members who were not directly involved in the field trial itself.

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awareness, ubiquitous computing, light-weight interaction, aging, visualization, home

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

INTRODUCTION
Many industrialized nations are facing the prospect, and soon the reality, of an aging population. This demographic imbalance instigates numerous social and economic concerns. One unresolved question is who will take care of these older adults as they age, given the respective decline in working-age adults to attend to their needs and pay for their care. The CHI community has paid particular attention to the investigation of home technologies to enable older adults to "age in place." [1,8] Primarily using ethnographic techniques, research in "aging in place" is being carried out in the home, in assisted living facilities and retirement communities. [3,4,6] Ideally, novel technologies in the home could sustain independence for older adults wanting to stay at home while allowing younger adults to stay in the workplace.

A Wall Street Journal article this past summer described the dilemma of working children of aging adults. Often geographically separated due to educational and job opportunities, working children struggle with how to care for an aging parent from a distance [10]. Recent research suggests that nagging concerns about the well-being of an aging parent can prompt a worried child to move his or her parent to an institutional care setting. This "peace of mind" deficit stems from a lack of daily awareness that, if available, would better inform an assessment of an older adult's independence and quality of life [8].

One proposed strategy for minimizing this peace of mind deficit is technology interventions that rely on some sort of sensing in the home of the senior adult and a visualization of that data for the adult child. Potential designs include the Digital Family Portrait at Georgia Tech [8], the CareNet from Intel Research [1], and even an Internet teapot commercially available in Japan that tells the adult child when her parent has made tea [5]. Despite the intuitive appeal of these designs, many questions remain.

First, would older adults accept this form of sensing in their homes, and more importantly, would they welcome and rely on the sensing or would they circumvent and game the system? External evidence points to both conclusions. A system such as a home security system can be reassuring, and relied on, especially for someone living alone. However aging adults are often stereotyped as purposefully masking any decline in abilities to avoid outside intervention.

Second, could these systems truly provide useful information to the adult children. What do they need to know? What level of complexity in the sensing is required? The previously mentioned Japanese teapot simply reports its use to an outside party. In contrast, some proposed designs require relatively complex, and potentially erroneous, activity recognition such as recognizing when someone has prepared and consumed a meal.

Third, how would the introduction of such as system affect the relationship between the adult child and the aging parent? The rosy view is characterized as a sense of increased closeness that comes from more awareness and reduced anxiety. A not-so-rosy picture includes an adult child, now armed with third-party information, who doesn't call as often to check in on things, and an aging parent who feels spied on and neglected.

Of course there is no one answer to these questions as each pairing of adult child to aging parent will have different characteristics. Some older adults will require more care and intervention than relatively passive monitoring, and other adults could be so fit as to resent the intrusion. A remaining question is then, what is the sweet spot for these types of systems, if one exists?

The purpose of this paper is to report on a single case study that did turn out to be within this sweet spot of utility and acceptance. Despite the quite good health of our older adult, both parties found sufficient utility in the system to continue using it even after we completed the year-long research study and removed financial support for the network connectivity. At one level, this research provides one set of answers to the questions just posed. At another level, it provides a path for subsequent research that aims to explore these questions.

Previous Work

One approach to supporting peace of mind for adult children concerned about their aging parents is the Digital Family Portrait (DFP) developed at Georgia Institute of Technology [7,8]. Initially based on wizard-of-oz simulated sensing, the DFP provides a qualitative sense of an elders daily activity (and by extension, their well-being) by embedding an icon for each represented day into the picture frame that surrounds the image of the elder. Like a traditional portrait, it is designed to be hung on the wall or propped on a mantle, blending with household decorations. Unlike the static picture in a frame, the digital frame changes with time, reflecting a portion of the aging parent's life. From general measurements of activity, to indications of the weather, the portrait attempts to capture observations that would naturally occur when someone lives in the same home or next door. Unlike most awareness interfaces that only provide a snapshot of the present and do not address the many questions about an aging parent that derive from trends over time, the DFP provides representations of the past as well as the present.

Similar to the DFP, researchers at Intel have developed CareNet [2], also using wizard-of-oz simulated sensing. Intel's CareNet addresses the needs of the elder's support network by displaying icons that represent the occurrence of important events specific to the needs of the elder such as meals, medications and outings. CareNet is intended to support the needs of the elder's care-giving network that can consist of a number of persons, some who have drastically altered their own lifestyles to provide the support necessary to allow the progressively aging elder to age in place. Though both the DFP and the CareNet displays to date are wizard-of-oz driven work addressing the needs of older adults and their families, by addressing the elders with a greater required level of support, CareNet is intended to be introduced in the home much later than the DFP.

Since this previous work shows sufficient promise to warrant taking the next step down their shared methodological trails, our work addresses this next step, the deployment of technology in a longer-term field trial without the use of wizard-of-oz sensing. This field trial involves the deployment of sensing technology in a private home to collect sensor activity over a one-year period, a time period that encompasses an intensive 6-week study period and serves as the focus of this paper. This work addresses many of the open issues described by Intel's CareNet research team in a recent publication:

"An important next step is to explore what happens to the acceptance of technologies like the CareNet Display when sensors are introduced to fill the role of human data collectors. Are elders comfortable living in a home filled with sensors? Do care network members trust the data reported by sensors? How is the network affected by sensor or system failure? A fully working system could also enable longitudinal deployments to uncover other unexplored issues. What happens when the technology gets beyond any novelty effects? How are the privacy controls used, and are they sufficient? What social issues do technologies like the CareNet Display introduce to the care network? Do such technologies contribute to a reduction in communications or visits with the elder overtime?" [1]

The contributions in this work are three-fold. We assess the feasibility of the Digital Family Portrait as a technology intervention to assist family members concerned about an older parent living alone. As an in-depth case-study, we report on anticipated and unanticipated uses of the system. In particular, this case study focuses on an older adult who is quite independent and who doesn't seem to "need" external monitoring. However, the older adult, her adult child, and her extended family benefit from use of the system. Finally we describe future challenges for the research community based on the questions that surfaced during this field trial.

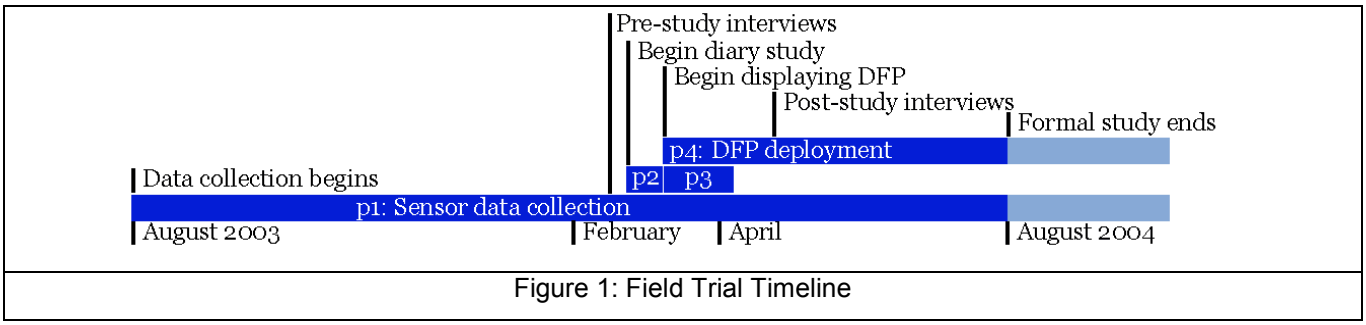

Figure 1: Field Trial Timeline

FIELD TRIAL OVERVIEW

For this field trial we studied two participants, an aging parent who we will refer to as Helen and her adult son who we will refer to as Will. This study is made up of four major phases as indicated in Figure 1. The onset of the study was August 2003 with the deployment of sensors in Helen's home. The sensing technology and layout of sensors is described shortly. Travel by Helen and then the arrival of winter holidays delayed the second phase of the study until February 2004. At this time, we conducted pre-interviews with Helen and Will and requested that they each begin filling out daily diaries. Following an initial two-week period of diary entries, we "turned on" the Digital Family Portrait as the third phase of the study. The daily diary during this phase asked about use of and conversation about the DFP. After four more weeks of daily diaries, we concluded the third phase with post-interviews. The final phase, which began concurrent with phase 3, concluded after we had collected one year of sensor data. As we will discuss at the end of the paper, Helen and Will still continue to use the DFP of their own volition and at their own expense.

The pre- and post- interviews with both participants helped us to determine the nature of the participants' daily routines, the participants' sense of awareness and feelings of connectedness one to the other, the nature and type of communication that existed prior to the introduction of the DFP, and the effect of the DFP on those communications. The quotes in this paper are pulled from these interviews.

For Helen's daily diary, we asked her to report her overall level of activity for that day, whether most of that activity had occurred in the home, whether she had been in direct communication with Will and if they had discussed the DFP, and her perception of how "connected" she felt to Will. For Will's daily diary, we asked him to report his perception of his mother's overall level of activity, whether he had been in direct communication with her that day, and his perception of his level of "awareness" of his mother as well as his perception of how "connected" he felt to her. Some parts of this diary worked quite well and other parts did not as we will discuss. One helpful addition is that Helen often annotated her diary with a short list of the things that she did that day.

Field Trial Participants

The two participants in this study, Helen a 76 year old retired postmaster and her adult son Will, live within one hour's drive of each other. Helen has lived in the same home, by herself, for the past 20+ years. She reports being in good health and still manages and controls all aspects of her life. She drives herself, cooks, cleans, maintains her own home (during the study she was doing touch-up painting) and does her own yard work. Though retired from her career as a U.S. postmaster, she still works regularly, both inside the home as an editor for a publishing house and outside the home as a volunteer at her church.

Aging Parent's Social Network

While active in her church, Helen's social network revolves almost entirely around her family, both her siblings and her children. She is the 3rd oldest of 4 children with a brother, in his 80's, living in Illinois, an older sister living in California and a younger sister also living in Illinois. She has 3 children that are also fairly geographically spread with a daughter in Missouri, a daughter in Minneapolis and her son, our participant Will, who lives on the east coast.

Helen keeps in touch with her family through the use of the phone. She calls her oldest sibling, her brother in Illinois, every day at 9pm. On those rare occasions when she cannot reach him by phone she will call her sister, also living in Illinois, to find out if she knows what is going on. She calls her sister in California twice a week on either Wednesday or Thursday and Sunday. She calls her sister in Illinois once or twice a week outside the occasional call to check up on her brother. She sees Will about once or twice a month when he comes to her house to visit, do odd chores and then go to dinner.

Though she has lived in the same home for 20+ years she does not rely on her neighbors or her contacts in the neighborhood for her social network. She professes to know her immediate neighbors but apparently rarely has any dealings with them outside the occasional "Hi! How are you today?" pleasantry. She reports

"There are days that I don't see anybody. I'm working in here. I don't happen to go to the store, don't go to church for anything."

When asked if she would mind if neighbors might have access to her daily activities through the DFP, she states that as long as she has family (though they are at some

Figure 2: Ambient display of the Digital Family Portrait

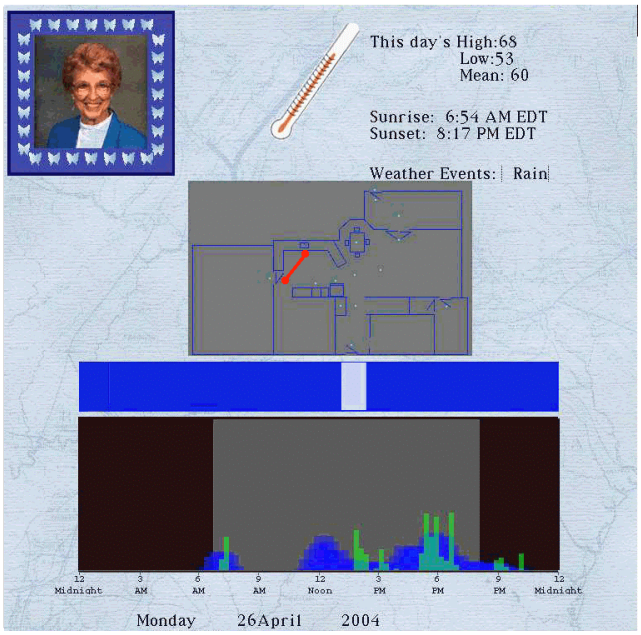

Figure 3: Detail screen of the Digital Family Portrait

distance) she can't see why the neighbors would be interested in it.

"Well, as long as I have a family I wouldn't especially want anybody else to… I don't know anybody that I am close enough to say I would like to have that (a DFP display) or that they would want to have it."

Though she has frequent contact with her church (she does volunteer work there on Mondays and attends on Sunday and Wednesdays), she does not think that they would be interested in monitoring her activities, so long as she has family available.

Will's Perspective

After hearing a university presentation about this research, Will approached our group about trying out the DFP. As we learned more about his mother, namely about her good health and independence, we were interested in understanding Will's motivation for using the DFP. Based on our interviews, Will does not seem concerned on an everyday basis of where Helen is or what she might be doing at any minute. Neither is he very concerned about the possibility of her hurting herself or about her not being able to care for herself. He is concerned

"… more along the lines of touching base with her… checking in… She used to play some golf but she's cutting back on it… after 18 holes she was real sore… then it got to the point were after 9 holes she was hurting pretty bad so her golf days are declining."

As the child living closest to her, he keeps up with her general activities.

"I'm fairly aware… I know she's doing proof reading and going to church to different functions… I'm aware of when she is traveling to go out to her sister's in California… "

He is also knows that Helen stays in touch with her siblings.

"Religiously… via the telephone… her two sisters she calls or they call her weekly… and she religiously calls her brother at 9 p.m. every night."

Digital Family Portrait Display and Interface

The DFP persistent display (Figure 2) presents a qualitative visualization of Helen's daily activity that is designed to fit naturally into a home environment alongside other family pictures on the fireplace mantle. Leveraging a familiar household object, the family picture in a frame, this design leaves the photograph untouched while populating the frame space with icons. Each icon represents a single day's level of activity for the 27 previous days and the current day. The previous day's icons provide a history of past conditions while the current day is updated hourly to represent the current conditions.

The viewer can acquire more detail concerning the level of activity for each of the days represented in the frame by touching the icon in question. The DFP detail display (Figure 3) presents important context information, such as the weather conditions for that day, the sunrise and sunset for that day, a floor plan of Helen's home showing the sensor locations and includes a slider for exploring the detailed information. Located at the bottom of the detail display is an activity graph.

The activity graph takes the 24 hour day, divides it into 96 fifteen-minute time periods, and displays the number of sensor firings (regardless of which sensor fired) as a bar

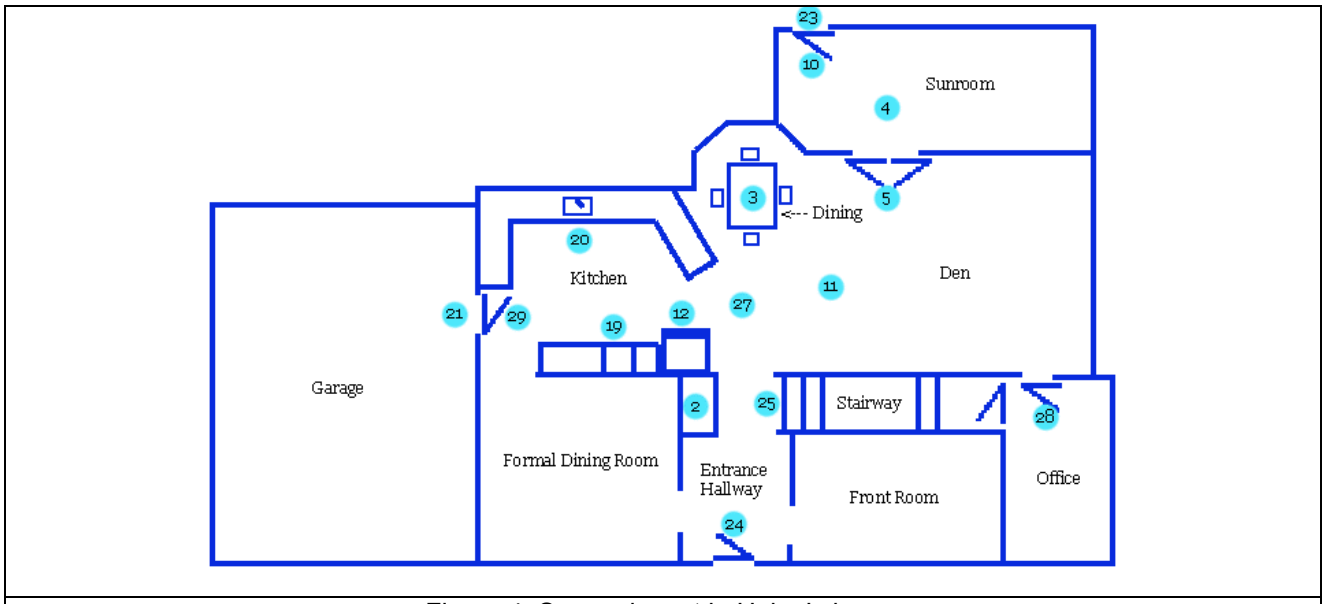

Figure 4: Sensor layout in Helen's home

graph. The graph of the current day (in green) is displayed over a one-hour running average of the sensor firings for three previous similar days (in blue). In this way, the activity graph shows what has happened that day against the backdrop of what typically happens on that day.

By dragging the slider across the top of the activity graph, the floor plan is animated to show sensor firings as they occurred that day. As pictured here, Helen has come back from shopping, and the display shows her most recent movement from inside the garage door to the kitchen sink as a trace from one sensor to the other.

Sensing Technology

To unobtrusively collect activity data, we installed sensors in Helen's home that did not require her to modify her habits in any way. We installed these sensors in the crawlspace of the house, attached to the exposed floor joists, in a manner that is completely invisible to anyone in the house.

We chose a commercial sensor product called Pulsors [11] that is built on the simple strain gauge and includes an electronic controller that converts the strain gauges' resistance change into the equivalent of a relay switch closing. The strain gauge is encapsulated in a plastic case that is easily attached to the floor joist (from the crawlspace) using an epoxy glue. Wires from the gauges go back to the controller. Each controller can handle four sensors. To interface the controllers to a computer we used a 32 port PhidgetInterfaceKit 0/16/16 board [9]. This board allows the sensor firings coming from the controllers to be read into a computer for identification, time-stamping and storage through a single USB connector.

Although many sensor options are available ranging from wearable RFID tags, to wireless motion detectors, to the sensors we used in this study, we opted for these sensors because they did not require any active use by Helen, they would provide relatively clean and reliable signals, and they would not be physically or aesthetically obtrusive in the home. We acknowledge that difficult privacy issues come into play with invisible sensing, for example, for visitors to Helen's home. However, given the low occurrence of such visitors, our concerns about invading Helen's home, and the low level of information provided by the sensors, we opted to pursue this path.

Sensor Layout

The monitored area of Helen's home includes a kitchen, a dining area, a hallway, a den, a sunroom and an office area (see Figure 4). Even though we were only interested in collecting gross activity by totaling sensor firings, we felt it was important to arrange the sensors logically so that the collected data could be used in future activity characterization. The question is, with an upper limit of 16 sensors (our sensor budget), where to best place them?

Clearly it is important to cover all exits. When there is no movement in the house, sensor firings at exits distinguish between a possible problem (the occupant cannot move) and the occupant leaving the house. A second place of general interest is the kitchen since meal preparation is important. By placing sensors in front of the sink, the refrigerator and the stove, we cover the classic kitchen triangle. The sensor at the bottom of the stairs not only indicates passage from one area to another, it indicates that Helen has gone upstairs to her bedroom suite. Placing it here forces this sensor to be the last to fire at the end of the day and the first to fire at the beginning of the next day. There is a sensor attached to the alarm system (sensor # 2), that is set when Helen arms the alarm system. The remaining sensors covered passage from one room to the next. Given Helen's good health and limitations of our sensing technology, we did not install sensors in her

upstairs bedroom or bath. As it turned out, Will would check for the first sensor firing at the bottom of the stairs as a simple indication that the night had passed well.

HOW DID WILL USE THE DFP INFORMATION

One set of questions for this field trial revolve around how the adult child (Will) used the DFP display and interface as a representation of his mother's activity. At the simplest level, the DFP provides two major affordances. The first is the ambient, persistent display of the picture framed by the butterfly icons. The second, the interactive "detail" screen, requires active input and supports rudimentary browsing of the sensing data. We organize our findings based on these affordances

Investigation Prompted by the Persistent Display

The DFP display in Will's home is located in the den, adjacent to the kitchen, a place where it is readily visible as Will leaves for and returns from work. In interviews, Will reported checking the display to see if anything looked out of the ordinary as he leaves the house in the morning and as he returns in the evening.

For example, curious about the appearance of a large icon for a particular day Will called his mom to try to determine what had happened that day without specifically mentioning that there was a large icon for that day.

"…to see if she volunteered any change of activity pattern… I found that she had washed the walls and was getting ready to paint… she was moving around a lot more and had obviously tripped the meter a few more times… the butterfly [icon] got big."

It is interesting to note that Will did not call his mother to question her about a large reading on the DFP display. The DFP information was the catalyst for the phone call, but Will let the information come out naturally. This kind of subtlety may be important for the acceptance of a DFP-style monitoring system and its integration into existing social protocols.

Investigations Prompted by Will's Curiosity

The detail screen of the DFP encourages different ways to explore the sensor data. One interface failure points to Will's motivation for understanding his mom's daily activity. The detailed display for a particular day includes a bar graph display, a floor plan of the house and a slider that, when dragged through the 24 hour day, animates the sensor firings on the floor plan. About using the slider Will stated

"…I was trying to get a feel for how she was moving around the house…"

Unfortunately the volume of the data coupled with the difficulties involved with moving the slider by hand made this prospective use unfeasible for this field trial. Future versions of the DFP interface will create sensor "trails" that persist for a portion of the day and slowly fade away.

For this field trial we took advantage of an existing alarm system in the home. As it happens, the alarm system could be used to signal our sensing infrastructure in the same way that a sensor would trigger it. Knowing that his mom didn't set the alarm on her home unless she was going to be away for a while, Will could investigate a displayed period of absence. He could differentiate between leaving the home for an extended period, shown by the "alarm sensor" firing followed by an exit into the garage, and leaving the home to do yard work, shown by the an exit into the garage to get the lawn mower without the "alarm sensor".

"In several cases I would go look to see if she had armed the alarm system or not because that would tell me that she was planning to be gone for a while… as opposed to going out to get the newspaper or cut the grass. So I could kind of tell."

His mother returning from extended travel is anxiety producing for Will. His typical plan is to repeatedly call her house after her expected return time although he dislikes intruding on her before she has settled back in. Having used the activity data collected by the DFP to determine that his mom had returned safely from her three week trip to California, Will stated

"Yeah, when she's traveling, I tend to worry a little more that something could happen… when I know that there is a risk of something travel related… I'm a little more aware of where she ought to be at a certain time and I will try to check in. One of the advantages of [the DFP] to me is to be able to resolve little concerns like that before they turn into undue anxiety over what's going on… Your paranoia's going to take over if you don't. "

"… I was intending to call her about something when she got back… rather than calling and getting her answering machine, [once data started arriving from her home] I had a pretty good clue that she had been there… she actually got back sooner than I expected so that was a kind of pleasant thing."

AWARENESS AND CONNECTEDNESS

Another set of questions for this field trial revolve around the dynamics of the parent and adult child relationship. We hypothesized that two characteristics of the relationship would change although not necessarily in a positive direction. First, we assumed that the adult child's "awareness" of his parent's activities would increase simply by providing more information. We also hoped that feelings of emotional "connectedness" between both parties would increase given this technological bridge. However, we acknowledged that connectedness could potentially decrease on the part of the older adult who perhaps feels more isolated if the adult child shifts the burden of maintaining an emotional connection too heavily on the DFP bridge.

Where awareness is more based on facts (e.g. "I know Mom goes shopping on Thursdays"), a kind of familiarity with

another's schedule, connectedness is more intimate, an emotional state of co-existence. Awareness can lead to feelings of connectedness, though it is not necessarily a precedent to connectedness. Photographs on a mantle are more about feelings of connectedness than they are about awareness. They provide emotional support as reminders of social and familial connections, and provide a feeling of comfort.

We attempted to measure changes of perceived awareness and connectedness by asking Helen and Will to rank these indicators using a Likert scale daily in their diary. This measurement technique did not produce any useful results. With Will, we simply saw a ceiling effect as his self-reported ratings of awareness and connectedness started high before we activated the DFP interface. With Helen, it is clear from an examination of the data that she closely tied connectedness to whether she talked with Will on the phone that day. Since the frequency of phone calls did not noticeably change, there was no shift in connectedness based on the presence of the DFP. However, interviews with Helen are more revealing.

In a manner similar to the photograph on the mantle, even though there is no physical manifestation of the DFP in her home, Helen reported feeling less lonely (and therefore more connected to her family) knowing that Will was watching out for her through the DFP.

"But, uh… if I'm feeling lonesome, I think, "Oh well, Will knows and so then I don't feel so lonesome.'"

Her statements initially surprised us as there is no physical reminder of the DFP system visible in her home. However the knowledge of the system, and likely the successful practice of having the system connect them appears to have significantly affected Helen's emotional response to being alone in her home.

PRIVACY AND (TRADITIONAL) SECURITY

Our final set of questions revolve around the cost and benefits tradeoffs, especially for the older adults, in assessing that the DFP system is of sufficient value to warrant adoption. In particular we want to understand the perceived privacy costs in comparison to the advantages gained from knowing that someone has more information about your general activity and well-being. We refer to this benefit as "security," not in the sense of information security, but akin to the traditional use of that word, feeling safe from harm.

The invisibility of our sensor technology initially arouses concerns about privacy. After all, if Helen forgets that she is being monitored because the monitoring technology is invisible, then she loses a level of privacy that most people like to maintain. We did not find this lack of a persistent reminder to be a concern for Helen. Generally speaking in our research, older adults are concerned about maintaining a careful balance between privacy and autonomy. While both are important, aging often necessitates some compromise. Giving up some privacy in order to maintain autonomy is a valid choice, the question is "How much privacy must be given up in order to maintain autonomy?" There is, however, a limit to how much and what type of sensor technology provides the correct balance. During the interview Helen stated

"Will talked at one time about having cameras up in the corners and I wasn't too keen on that… I just didn't know that I wanted a camera watching me."

Our approach is to opt for sensing that does not distinguish between occupants. It is possible to use this type of sensing in this research because Helen lives alone in her own home and has few outside visitors. The sensing technology has the advantage of not requiring any active participation in the sensing system on the part of the Helen; there were no badges that must be worn or sensors that must be carried. All the participant need do is to live her life as she would normally.

The exit interview suggests that we have selected a sensor technology that supports a reasonable balance between privacy and autonomy.

"…I would say that I feel more comfortable knowing that he knows that I'm moving around. He knows that there's something going on down here. And if he doesn't get something with a malfunction, he calls."

Even though the sensor technology is invisible to the participant, Helen appears to draw comfort from the knowledge that her son is monitoring her activity. Surprisingly, the occasional malfunction of the equipment causes her confidence to increase in the system. Since a malfunction cannot be distinguished from no activity, Will made a phone call to check. This phone call acted as a system test to Helen, demonstrating that the system is indeed being monitored.

Additionally, the choice of sensing technology that does not identify the person reduces the privacy concerns that arise when a third party, not knowing that monitoring is going on in the home, enters the monitored space since the third party is not identified or distinguished from the participant.

Helen's overall position about having this sensing technology deployed in her home can be summed up by her comment

"I don't feel imposed upon, or spied upon or anything."

Another indication of perceived value came from Helen volunteering that she wished that she had the DFP when her mother was alive.

"I wish it had been available when my mother was living and I lived in all these other towns while she was back in Illinois. (Helen's job as a postmaster moved her from town to town, predominantly in the mid-west). It would have been nice because she lived alone for 25 years and went down hill over that period of time. It would have been nice to

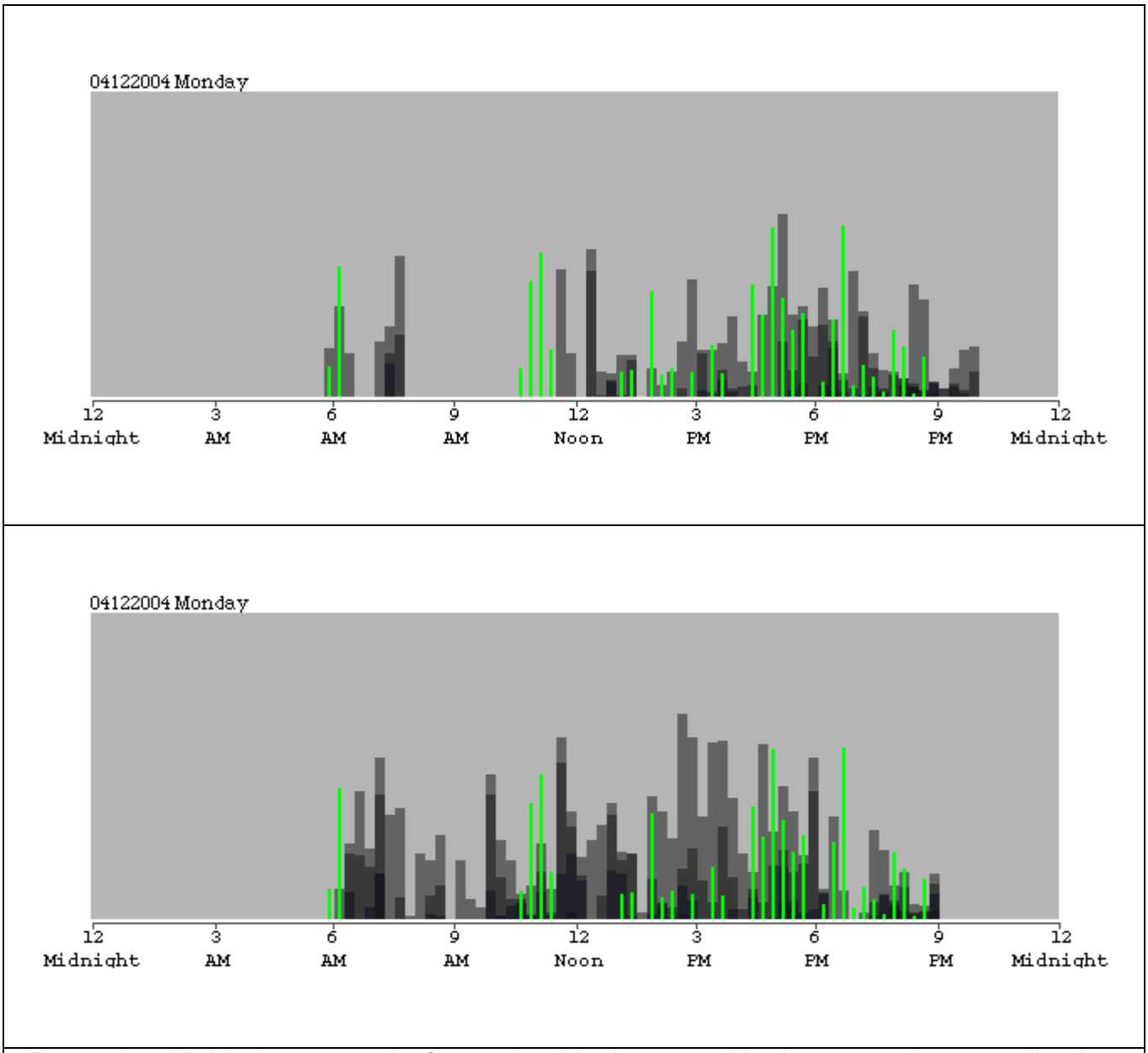

Figure 5 A and B: Monday compared to four previous Mondays versus Monday compared to 4 preceding days

know that she was up and around and moving but…That's when I called her. The telephone got of use…"

Helen and her siblings had set up an ad hoc phone call system to keep up with their mother.

"We set up a system over the last years of her life where I called twice a week. Somebody else (one of the other of the 3 siblings) called twice a week and then somebody else called twice a week… so we covered 6 days and we all called on Sunday… Or at least we all were supposed to call her on Sunday. Sometimes we did and sometimes we didn't. We tried to set that up so that somebody talked to her every day. It's kinda hard cause I was working…"

Will's Perspective on Level of Intrusiveness Needed

If the sensing system is acceptable to Helen, then the subsequent question is whether the information provided by the system is of sufficient utility for Will. Will reports

"At this stage I'm loosely connected as opposed to intimately aware of what's going on. I don't think I need to be in her life, intruding in that respect… I imagine that I will be more aware as time goes on… but for right now I think we are at what I consider the right level."

Value for the Extended Family

Although we did not interview Helen's other children or her siblings, we were pleasantly surprised to hear Helen report that other family members were interested in the system:

" …(my daughter in Missouri)… I can't remember why but she was very interested in it (the DFP field trial). She was very pleased that we were doing it . It puts her mind at ease… even though it is not her (participating in the field trial), she knows it's in place."

CONCLUSIONS AND FUTURE EFFORTS

The core research question for this study is: Would a family find sufficient value in the DFP's ability to convey the general activity of an older adult to her adult child for them to successfully adopt the system? The fact that Helen and Will continue to use this system today, over a year after its deployment, is quite encouraging. Will both used the DFP in anticipated and unanticipated ways such as noticing surprising activity readings, inferring when Helen was out doing errands, and monitoring her return from travel. As the proponent for this technological intervention, he adeptly leveraged this new information without causing undue concern or discomfort for his mother.

Helen's acceptance and emotional reliance on the system is both a little surprising and encouraging. Her volunteering that the DFP made her feel "less lonely" and that she wished the DFP had been available when her mother was alive was unexpected.

Of course this study involves only one family. However, the success of the system with an older adult as healthy as Helen is an indication that the potential space of possible users may be larger than initially anticipated. In our future research, we will investigate the utility of a DFP-like system for older adults who have more significant health concerns.

Mining Sensor Data

Although this field trial concentrates on a six-week period, the activity data collected during the 12 months of monitoring represents a unique and valuable set of data worthy of further exploration. In the literature there is an absence of research data on a person's movement in his or her own house that is not biased by self-report or by third-party observation. We are in the process of several threads of analysis that would provide more sophisticated capabilities for future versions of the DFP.

Mondays are like Mondays

Above all, the crux of the question posed by adult children concerned about an elderly parent is "Was today a normal day?" Intuition tells us that certain days of the week will have a regular pattern. People tend to pick certain days to carry out particular tasks such as the laundry or yard work. Add to these routines the pattern of activity that is imposed from the outside such as work obligations, the pace of weekly events and even the schedule of trash collection, and life often assumes a semi-regular pace that changes slowly with more global rhythms such as seasons.

Although retired, Helen's schedule has patterns driven by her preferred routines and outside commitments. She has volunteer work on Mondays, goes to church on Wednesdays and Sundays, and does her yard work on Fridays. This regular pattern of activity provides the opportunity to characterize certain days of the week, and with this characterization, provide a baseline such that the adult child can better determine whether or not a chosen day is "typical" or not.

One of the simplest ways to characterize a day is to ignore which sensors have fired and accumulate the number of sensor firings over a particular time period. Doing this calculation for the current day and displaying it against the background of previous similar days of the week provides a simple means of comparison. We took this approach in this field trial and it appears to reasonably characterize certain days making them distinct from other days. The best example is to look at Mondays which has a strong pattern (see Figure 5).

In Figure 5A, we see a single day, Monday, April 4, 2004 shown in green against the background of the 4 previous Mondays shown in gray. In Figure 5B, we see that same day in green but displayed against the background of the 4 previous consecutive days that include the previous Thursday, Friday, Saturday and Sunday. The pattern of green bars in Figure 5A clearly match the previous consecutive Mondays better than they match the previous consecutive days as seen in Figure 5B.

Going back to our data, we now have the opportunity to exhaustively examine similarities in common days (e.g. all Mondays) versus consecutive days (e.g. Thursday, Friday, Saturday and Sunday). Diary entries will help us determine days that were truly unusual in comparison to typical days.

Trends

What appears to be the second most common concern held by adult children about their aging parents is knowing if there are subtle declines in capabilities or behavior. Examples include sleeping less as well as sleeping more, eating less, and general reductions in activity and abilities such as climbing stairs

The data available from the DFP sensors includes the potential for modeling the physical space (e.g. these three sensors are part of the kitchen), however the data is unlabeled in that there is no training data for what certain routines "look like" in the data. The future challenge is to determine what types of routines can be gleaned from this data and then to identify gradual changes in those routines. Although we do not know of any progressive declines in Helen's abilities during this field trial, we do know that her behavior shifted gradually with the changes in the seasons. We also hope to make this data available to other research groups as a general test data set for evaluating pattern detection algorithms.

Sensing Multiple People

One potential hiccup in the data is when there are multiple people present in the home. This scenario has the potential to double the sensor firings in the house and to undermine any inferences made from the data. We plan to explore the feasibility of identifying discontinuous sensor firings as an indication of multiple people in different rooms. If we can detect these firings, then the next step is to work backwards and forwards through the data to determine when the additional person(s) entered and left the house.

Future Field Studies

A considerable amount of effort is needed to conduct a study as seemingly simple as this one, especially for the first time. Coordination with one extended family, but two homes, can be challenging. We were fortunate in that both Helen and Will were motivated to participate although the initial motivation came from Will. Installing a network of sensors in a home is still not routine. Even the pragmatics of negotiating third-party payment for broadband connections proved more tiresome than predicted.

With this experience, we have now packaged a more easily deployable version of the DFP using X10 wireless motion sensors. The system now includes software for entering a home floor plan, configuring and calibrating the sensors, and establishing the connection with the portrait display in the other home. Part of our future work involves partnering with other research groups to deploy this technology in related research trials.

Combining Medical and Activity Monitoring

One such effort is combining our activity monitoring and wearable medical monitoring for older adults who have more severe medical concerns. We are working with XXX to investigate the combination of wearable blood pressure and glucose level monitors with activity monitoring for older adults with Type 2 diabetes. Different visualizations are needed for the clinical physician reviewing data periodically, for the older adult monitoring his or her own data, and, for now, the traditional DFP interface augmented with medical data for family members. We are interested in how these two types of data aid families in noticing deviations in behavior and aid clinicians in understanding the larger context surrounding medical data.

Activity Monitoring for Proactive Interaction

We have also been approached by another research group interested in using the DFP technology as a proactive interface for older adults grappling with debilitating depression. In addition to providing awareness information to concerned family members, the system would detect extended periods of low activity and attempt to encourage more healthy behavior. A personalized visualization would also help the older adults assess their good and bad periods, perhaps helping them draw the correlation between more activity and feeling better. Of course this scenario introduces more challenges for adoption and acceptability of the system by older adults.

Both avenues of future field trials point to the potential utility of the older adult reflecting on information about themselves as they work toward maintaining or improving their quality of life and independence.

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