

# Social Networks as Health Feedback Displays

Social networks have thus far served primarily as analytic tools for social scientists. Leveraging pervasive computing, this new research transforms social-network models into behavioral feedback displays. These ambient displays, which reflect data on remote and face-to-face interaction gathered by wireless sensor networks, were intended to raise awareness of social connectedness as a dynamic and controllable aspect of well-being. An interdisciplinary health technology research group at Intel recently developed and tested prototypes in the homes of older adults and their caregivers. This article reviews the psychological rationale for the project and highlights some reactions of participants to the displays.

“Loneliness is a part of old age, and there ain’t a damn thing you can do about it.” These words, the proclamation of an 82-year-old research participant, express the social helplessness many elderly people feel when coping with age-related changes such as retirement, the death of a spouse, and a diminishing network of surviving peers and relatives. Such changes often bring about *social disengagement* – withdrawal from the relational stimulation and support that can protect against a spectrum of illnesses.

Throughout life, many people inaccurately perceive social circumstances as beyond their control, exaggeratedly stable, and generally unchangeable. Situational, temporary isolation can be interpreted as a permanent state, blinding people to opportunities for social

contact. These perceptual tendencies, combined with the importance of social ties to our health and concept of self, invite new tools that enhance our awareness and control of social engagement. Our multidisciplinary research group at Intel has developed social-network visualizations, continuously updated with sensor and self-reported data, to foster awareness and empowerment of social health. Figure 1 (next page) shows an early conceptual model of the display. We developed and tested these visualizations and their underlying technology platform of sensor networks, online journals, and algorithms during three-month in-home trials. Further details about these technologies and health research at Intel appear elsewhere.<sup>1</sup> This article focuses primarily on the rationale for social-network displays; subsequent reports will detail methods and findings.

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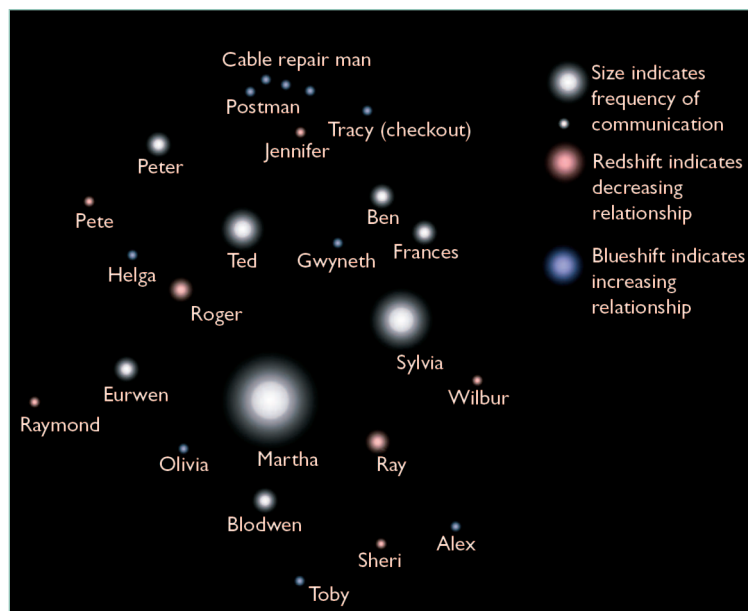


Figure 1. Conceptual model. Our first “solar”-inspired model depicts trends of social interaction. The elder sits in the center as the sun, surrounded by planetary representations of specific friends and family members. Inward movement reflects greater interaction with the elder.

## Applying Social Networks to Real Life

Anthropologists, sociologists, and psychologists have long used social networks to model communication pathways among groups. Schematics of social units, generated by scaling algorithms and other mathematical modeling tools, reveal communication flow, central individuals, social sub-clusters, and the pivotal individuals who link disparate clusters. These analyses help characterize current dynamics within a group and predict patterns of social change.<sup>2</sup> Social-network modeling is beginning to influence real-life practices – the social transparency afforded by tools such as LinkedIn ([www.linkedin.com](http://www.linkedin.com)), for example, has drastically changed the processes of dating and job searching.<sup>3</sup>

This article explores a simpler, more colloquial understanding of social networks: their reflection of an individual’s social health. This work employs egocentric social networks – derived from interview and sensor data – to reflect trends in interactions with friends and family. In addition to describing social states, these network visualizations were intended to motivate social engagement among older adults, help them become more aware of their ability to spark interaction, and help their caregivers become more

effective social liaisons. Ultimately, our research is aimed at enhancing elders’ quality of life and general health, increasing their autonomy, and helping protect against illnesses with a demonstrated social link, such as dementia.

## Social Activity as Health Data

Social science and medical research has consistently pointed to social engagement as an important indicator and predictor of health status. Longitudinal studies have demonstrated the protective and sometimes even therapeutic value of social engagement for illness ranging from the common cold to cancer.<sup>4,5</sup> The protective value of social engagement is suspected to stem from a combination of instrumental and emotional support from other people.

Our ethnographic research points to influence as another key dimension of social engagement.<sup>6</sup> The experiences of giving to and having an impact on others could be as important for health as receiving support. We continually encountered the desire of elderly people to feel helpful – for example, by teaching, parenting, making people laugh, and fixing things – and saw identities crumble when the opportunities to influence others were lost due to physical or cognitive decline. The symptoms of illness, such as forgetting names or having difficulty tracking conversations in the case of dementia, often remove people from the very sources of social support and stimulation that could help protect them from further health decline.

In our ongoing research with older adults and their caregivers, it became clear that health technologies should support individuals’ networked sense of self as well as their physical health and independent functioning in daily activities. We expected that mirrors of social activity, mapped according to a person’s network of friends and family, could help elders maintain the social ties that are often threatened in later life. We wanted to motivate contact by increasing elders’ self-awareness and confidence in their ability to initiate and sustain contact.

## Health Feedback Displays: Advances and Barriers

Physiological and behavioral feedback displays have long been a component of medical treatment for a variety of problems, particularly pain disorders. Biofeedback of muscle tension, for example, can help migraine sufferers voluntarily relax and tighten the muscles associated with their pain; this

therapy increases awareness and control over subtle behaviors that often lie beneath awareness. The concept of biofeedback has even migrated into various consumer-oriented applications for physical health: predictive games, for instance, have helped diabetic children understand how to manage their glucose levels.<sup>7</sup> Behavioral feedback is another effective tool for monitoring health change. Several companies now invite users to view pedometer readings over time and evaluate their progress in achieving certain fitness goals (for example, [www.sportbrain.com](http://www.sportbrain.com)), and digital imaging has helped diabetic patients reflect on the physiological effects of their dietary choices.<sup>8</sup> These tools share key qualities: they reflect contextually rich data, they empower individuals to investigate their health, and they highlight opportunities for healthful change.

Unfortunately, significantly less compelling feedback tools are still the only choice for most patients. Clinicians commonly encourage patients to manually log behaviors such as diet, sleep, exercise, mood, or energy. These logs can be informative, but few patients can tolerate the burden and tedium of consistently documenting their behavior. Additional barriers to self-monitoring include the difficulty of tracking multivariate environment-behavior-health relationships, the disconnects between an individual's experience and clinical metrics, and the challenges of recalling and capturing hourly variability in symptoms, mood, cravings, or energy levels. Some notoriously ineffective health displays persist as the only choices for patients. The bathroom scale, for example, accurately reflects an important health indicator (weight) and its behavioral determinants (eating and exercise), but it's a tool many people avoid or merely tolerate, often experiencing it as a slap on the wrist rather than a helpful nudge. Another reason such displays can fail to motivate people is that they reflect only a snapshot in time, with no historical trending or actionable feedback.

A new area of health technology research — called *embedded assessment* — combines health monitoring with motivating feedback that is relevant to an individual's short and long-term health goals.<sup>9</sup> This approach relies on pervasive computing to capture meaningful trends and to present contextually appropriate feedback. In embedded assessment, long-term health vulnerabilities are matched with an individual's current concerns, even if these immediate concerns aren't explicitly health-related. Health feedback is tailored to an

individual's stage of life, concerns, goals, and risk profile. For example, cardiovascular risk factors such as weight gain and hostility can be addressed in terms of strategies to improve interpersonal effectiveness and physical appearance. Another key feature of embedded assessment is the integration of monitoring into an individual's compensatory and preventative health strategies. Behavioral feedback is framed in such strategies to help people work around an impairment (such as rehearsing names to compensate for poor memory) or to ward off a potential problem (such as exercising to prevent weight gain). Assessment occurs by monitoring the effectiveness of these compensatory and preventive strategies.

### Highlighting Variability and Change

A key feature of the social displays we've developed is the reflection of behavioral variability and opportunities for change. Impetus for this direction comes from two streams of psychological research. First, M.E.P. Seligman's research on attributional style — our quick inferences about causality in everyday life — suggests that people can improve their physical health, psychological well-being, and even their professional success by recognizing the temporary nature of negative situations.<sup>10</sup> Second, work on *mindfulness* indicates that a meta-awareness of physical and mental patterns can help individuals cope with and recover from a variety of emotional and physical health challenges.<sup>11</sup> Studies in these areas indicate benefits in acknowledging the dynamic qualities of

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The current research applies principles from cognitive-behavioral and mindfulness therapy to address social isolation. Ubiquitous computing and affective displays are employed to visually convey the temporary nature of isolation and to reinforce progress toward social engagement. Ultimately, these technologies should help us enhance the

effect of these therapies and extend their reach to a far wider audience than that which currently has access to psychotherapy.

### The Dynamics of Social Engagement

Social connectedness is often regarded as a stable construct or personality trait. We often describe people as either loners or joiners, or, in M. Gladwell's terms, as "connectors, mavens, and salesmen."<sup>12</sup> Measurements of social engagement also imply more consistency in social tendencies than might be warranted. Even questionnaires specifically designed to assess recent social behaviors and feelings are unlikely to reveal changes over brief intervals. There is stability in the personality characteristics, such as extroversion, that influence the extensiveness of individuals' social networks, but there is more fluctuation in the composition and configuration of these networks than current measurement tools can accommodate. With the exclusion of some recent work,<sup>13-15</sup> little has been done to capture and display fluctuation in individuals' social networks, particularly over short time periods.

In contrast to this stable characterization, the gerontology literature indicates that social-network structures change significantly over a person's lifespan. Most research suggests a relational pruning or network simplification with age, but questions linger about whether this change is truly desirable to the person with dwindling social ties.<sup>16</sup> In our ethnographic studies, we encountered people who were very socially active in midlife, but who became reclusive due to age-related barriers and decreased opportunities for interaction, particularly spontaneous gatherings. These changes most often arose from the death of a spouse, relocation in later life toward caregivers and away from friends, deterioration of eyesight and subsequent driving restrictions, or symptoms of a stigmatizing illness such as dementia.<sup>17</sup>

Our household interviews suggested that many elderly people miss the spontaneous peer contact they enjoyed in previous phases of their lives, but become resigned to solitude because of the tremendous effort required to see friends.<sup>17</sup> Many resolve dissonant feelings about this loss by re-orienting their energy toward their families. Some acknowledged isolation reluctantly; in other cases, frustration was expressed indirectly via a caregiver who felt overwhelmed as the elder's primary social liaison. Women seem to experience these

challenges more keenly: they're more likely to live alone later in life and more likely to find themselves sandwiched between multiple caregiving responsibilities. A representative example from our study is an 80-year-old widow, who, following health problems, moved away from most of her friends to live near her 50-year-old daughter. Her daughter, struggling to balance new caregiving responsibilities with the demands of her own marriage, family, and career, became exhausted by mediating all social contact for her mother.

We also saw signs of variability in social connectedness over very short time periods. One woman we interviewed, for example, enjoys a great deal of social contact during the week, but dreads the loneliness she experiences on the weekends. Her weekend routine isn't so different from her weekly schedule, but it feels emptier because she suspects that other people are busy with their families on Saturday and Sunday. Other participants in our study despise the evening hours: "This place is a morgue after 7 p.m.," one woman bemoaned about her retirement community.

Periodic assessments and surveys can't always capture these episodic feelings of isolation or even the gradual, more permanent shifts that occur over longer time periods. Pervasive computing could prove more effective than clinical assessment in assessing this variability and in identifying the time periods in which solitude is most painful for a particular individual. Intuitive displays of these trends could help people recognize their social patterns and develop and evaluate new strategies for initiating social interaction.

### A Design Metaphor for Social Networks

Several criteria guided our choice of a social-network display. We wanted an organic symbol of social life that held emotional and visual appeal, but that also resonated with people across age, race, gender, and educational lines. This symbol also had to have a recognizable structure that intrinsically involved movement. These criteria led us to select a solar system. Figure 2 shows the solar model that we deployed in our study.

### Configuring the Display to Invite Change

In addition to symbolizing social relatedness, the display needed to empower and motivate viewers. Our goal of "persuading" elders to self-reflect and initiate social interaction guided two additional



design directions: an egocentric model and suggestive mirroring of social behavior.

### Why an Egocentric Model?

A primary goal of our project was to put elderly people in control of their social activity and to help them envision possibilities for greater social connectedness. Ideally, the person viewing these displays would cease to perceive loneliness as an inevitable consequence of old age, viewing isolation instead as a temporary state that can shift via behavioral strategies. Our intent wasn't to present the elder as a speck in the universe, but rather to present compelling opportunities to draw others into the center of his or her world. For that reason, the elder is positioned at the center of the display – as the sun. Family and friends rotate around as planets; their proximity is determined by the extent of their contact and is updated hourly. The duration of contact is weighted by the modality of interaction and the other person's emotional closeness to the elder. The planets' inward movement reflects and reinforces the elderly person's social efforts.

We designed this egocentric model as a tool for both elders and their caregivers. Without an effective social liaison, many elders can't sustain weaker social ties, which are critical for well-being.<sup>18</sup> For this reason, we placed social-network visualizations in the homes of both elderly people and their primary caregivers. The primary caregiver, typically an adult daughter, could monitor her own contact with the elder as well as that of other family members and friends. We expected that the displays would motivate caregivers to either increase their contact with the elder or develop strategies for distributing responsibilities.

### Suggestive Mirroring: Inviting but not Prescribing Change

Another major design goal was to invite change in a person's social interactions without prescribing specific actions. This design intention is aligned with the clinical practice of *motivational interviewing*, in which change is invited by presenting personalized health information, and with *persuasive computing*,<sup>3</sup> which requires the intention to change among end users. There are several reasons to avoid explicit social directives – namely, the margin of error in exploratory technologies and the cognitive benefits of social planning. The latter (picking three compatible friends to take a walk, for example, or planning rounds of invitees for a

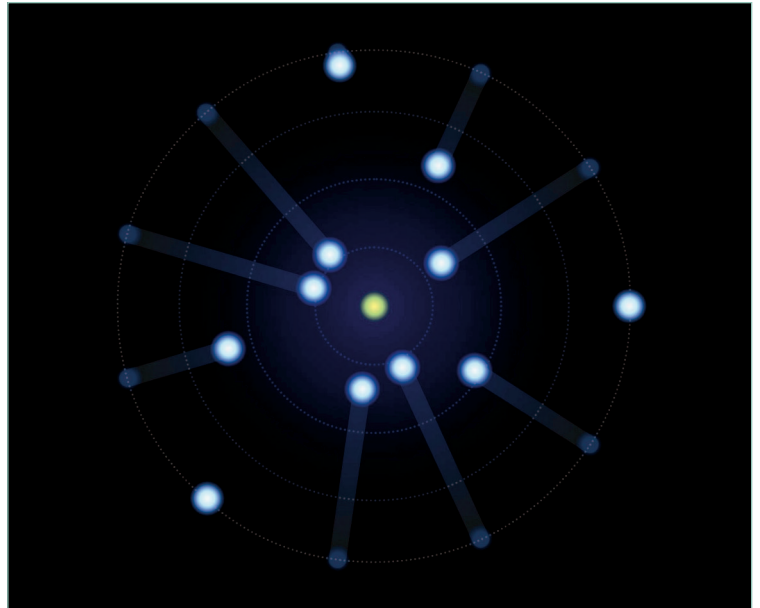
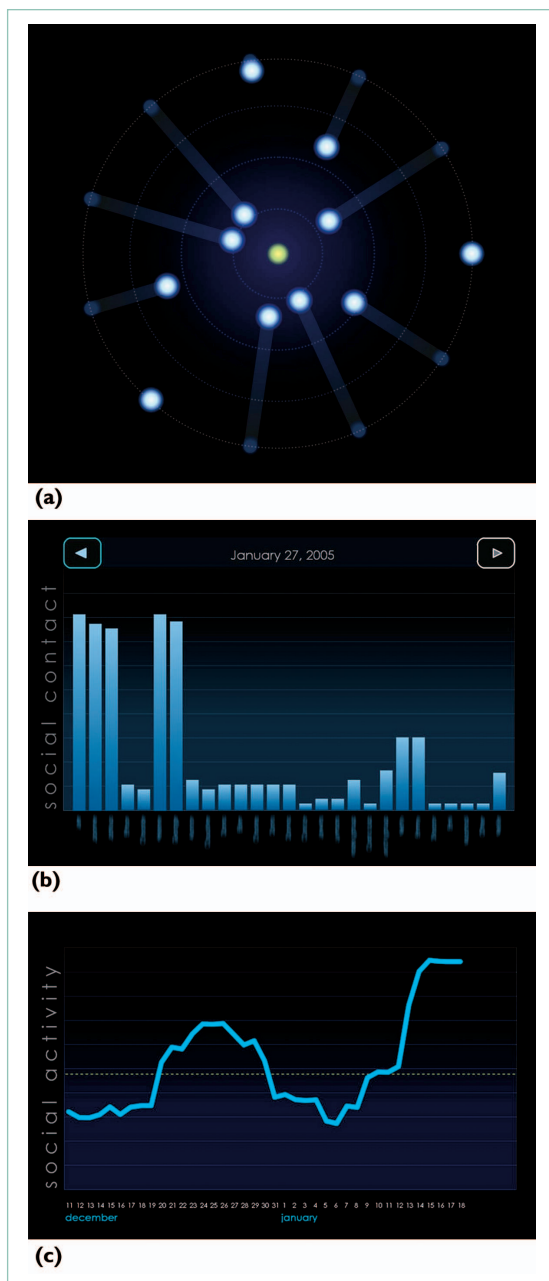


Figure 2. The solar model of social activity. The elder, positioned at the center of the display, is surrounded by planetary representations of friends and family. Sensor data from the phone and infrared badges generates the movement toward and away from the elder. This revised model employs a continuously updated “social index” or rolling average of interaction with the elder. A white trace indicates movement from baseline.

dinner party) provides cognitive exercise similar to the challenging puzzles many people undertake to ward off dementia, but a prescriptive prompting system for socializing would undermine this cognitive stimulation. Given the rough inferences that sensor technologies allow and the nuances of social engagement, we deemed *suggestive mirroring* to be a more appropriate goal than prescribing. In short, our goal wasn't only to increase the raw amount of social contact, but to encourage reflection and self-efficacy. These goals are at odds with explicit directors or features that would automatically connect the elder with others, but they align well with tools that can invite self-reflection and intentional planning.

### Modalities of the Social-Network Display

Our primary lens on the elder's social network is the solar display in Figure 2, which is a simplified version of Figure 1. In this display and other technologies that we developed for our study, we sought to empower elders in a style that differed from most “assistive technologies.” Given our desire to foster social engagement, it seemed particularly important to avoid socially stigmatizing



**Figure 3. Social-network modalities.** The (a) solar display and (b) bar graph depict the elder's current level of interaction with each individual in the network (lined along the horizontal axis in the bar graph). A menu button lets users scroll backward and forward in time to see information on each day of the study. The (c) line graph shows the sum of the elder's social contact on each day. A dotted line across the line graph shows the average social activity during the study's baseline phase.

tools. We also wanted to create prototypes that would appeal to middle-aged caregivers as well as

their elderly parents; in particular, we wanted to see how adults in midlife would adopt the tools not only for caregiving but for managing their own lives.

The solar display itself conveys minimal information to the casual viewer; it could even be mistaken for a screen saver. To avoid stigmatizing the elder and to preserve a simple design, the social contact's photo and name appear only when the respective planet is scrolled over. Another feature on the solar display is a historical trace: a line between each person's initial and current level of contact with the elderly person at the center. Users toggle between the solar display and several other views, including a line graph (a longitudinal indication of the elder's aggregate contact with everyone in the social network) and a bar graph (showing levels of contact with each contact on a given day). Figure 3 depicts the three image modalities; a fourth modality – a text summary of social activity – was also available to users.

### Implementation and Testing

We tested these displays – along with a platform of proactive health technologies that support social engagement – during a three-month in-home trial with six dyads of older adults and their primary caregivers. We conducted the trials as case studies with a baseline–intervention design. During the baseline phase, we gathered sensor and self-reported data to average the participants' social activity levels. During the intervention phase, we introduced the social health displays. We tested two additional applications in this phase (bi-directional presence lamps for the elder–caregiver dyad and a contextual prompt for the phone that showed the caller's image, name, relationship, and gist of his or her last conversation with the elder), which a more comprehensive report will discuss. Collection of sensor and self-reported data continued during the intervention phase and were used to continually update the social health displays. We also conducted in-depth interviews, which included discussion and mapping of relationships, at key junctures throughout the study (specifically, during intake, end of baseline, and end of intervention).

To quantify social activity and compare levels of interaction before and during the study's intervention phase (the six weeks of exposure to the social health displays), we relied on measurable indicators that home sensors could detect: the duration of visits and phone calls. Although these measures don't capture the nuances of

social engagement, we suspected they would provide a preliminary benchmark, similar to the way that pedometer readings estimate physical activity. The social index we used for our visualizations is a summary of interactions weighted by the closeness of the social contact to the elder, the modality (in-person visits, for example, were weighted more heavily than phone calls), and each interaction's duration. To this predominantly sensor-based index, we added self-reported interactions that occurred outside the home. The social index was updated hourly and the displays recalibrated accordingly. Sensor data was validated with self-reported interactions (an online journal personalized with social contacts' names and photos).

Our system included several components: wireless sensors adapted from commercial products; infrared badges and beacons; a phone sensor board linked with a caller ID service; mote radios to relay sensor data to an in-home laptop server; and a laptop for social health displays. A detailed report of our methods and findings is in progress.<sup>1,17</sup>

## Preliminary Observations from the Field

We're currently analyzing the sensor data and qualitative findings from the interviews. Our preliminary analysis of sensor data indicated a rise in social activity during exposure to the social health displays. Emerging themes from our interviews shed some light on why this increase occurred.

### Adoption and Preferences

Participants generally found the displays interesting and interacted with them frequently. Even people who sometimes disagreed with the depictions of their social activity nonetheless expressed attachment to the displays and disappointment when we removed them at the end of the study. Most elders preferred the solar display and used it as their default setting. They appreciated its circularity and movement, and used it as a game-like stimulus for family conversation. Several caregivers expressed a preference for the line graph; one woman explained, "The solar display tells me more about how much *other* people are interacting with my mom, but the line graph is what really tells me what *she's* doing." People preferred all image modalities over the text adaptation.

### Elder Reactions

Interview responses echoed preliminary quantita-

tive findings that elders were more socially active when exposed to social-network visualizations.<sup>17</sup> This increase appears to follow from greater awareness of variability in social activity levels, consequent desire to increase social contact, and enhanced communication with caregivers about combating isolation:

- Elders were surprised by the ups and downs in their social activity levels as depicted in the displays. They expressed interest in spotting downward trends early on and intervening to avoid isolation and depression.
- The displays also facilitated dialogue between elders and their caregivers about social isolation. As one caregiver explained, "the displays gave us a vocabulary [and] permission to discuss social concerns," particularly her mother's lack of peer relationships.
- The persistent centrality of family members in the elders' social displays drew attention to deficits in peer contact. By the end of the study, one elderly woman had formed a list of old friends with whom she was going to reconnect, another started intensifying interactions with acquaintances from her choir group, and another became significantly more socially involved in her retirement community.
- Elders' enthusiasm for tracking their social interaction (via the online journal) increased markedly with the introduction of the social displays. Surprisingly, participants experienced the journal tool as a therapeutic tool once they associated it with the visual feedback from the displays. This increased interest in self-monitoring provides compelling support for the principle of embedding feedback into health assessment technologies.

For the most part, we observed subtle shifts away from social passivity, demonstrated in small but meaningful actions such as preparing food for visitors or a family gathering, initiating a phone call rather than waiting to be called, or driving somewhere rather than asking to be picked up. We also saw some major shifts, such as a woman who began tutoring elementary school students. Another exciting trend was perceptual resolution — an ability to differentiate among and relate to individuals previously blurred into an amorphous sum. One woman, who initially referred to people in her retirement community in terms of activities — "the dominoes group," "the arts and crafts

group,” and so on – later referred to the individuals in these groups by their names and with appreciative details about their personalities and quirks.

### Caregiver Reactions

The displays also appeared to help adult children modulate their caregiving responsibilities. Specifically, the displays generated awareness – and, in some cases, outreach – among children who weren’t terribly active in their parents’ care, provided additional information to caregivers who were content with their level of involvement but

interests. For this woman, success was visually evidenced by the movement of other family members toward the center of her mother’s social network display and her own movement away from it. Another woman, who at the beginning of the study insisted that her father was entirely self-sufficient and that she was “by no means a caregiver,” began to see how much she was doing for him: “I now realize that I kind of am a caregiver, and I feel okay about pushing him to see other people.” This perceptual shift was validating: she felt more confident that she played a valuable family role and more energetic about helping her father maintain outside social ties.

## The persistent centrality of family members in the elders’ social displays drew attention to deficits in peer contact.

who wanted additional reassurance about their parent’s well-being, and, for overburdened caregivers, motivated strategies for distributing responsibility.

The displays were most helpful for those adult children who were very actively involved as caregivers. They appreciated the validation of their caregiving activities and enjoyed a playful competition with their siblings about who could be the closest planet (best child). Family members made a point of checking their positions in the elders’ social network when visiting either the elderly relative or the primary caregiver, and some even conducted informal tests to see how much contact would make a perceptible difference in the display. Any system failures in registering phone calls or visits from these relatives elicited strong complaints.

Ultimately, the displays sparked new insight among some participants about the significant time and energy they devote to caregiving. The woman described earlier as sandwiched between caregiving responsibilities explained that seeing her central position in her mom’s network, week after week, made her realize how many other areas of her life she had been neglecting. Consequently, she initiated several strategies to bring other people into her mom’s daily life and started scheduling time for her own hobbies and

Exciting directions emerged from our trials for future research and design. Two general areas are modeling more complex dimensions of social interaction and capturing data in a wider array of environments. Several extensions of this research, underway with a variety of partners, include

- using mobile systems to measure and support interaction outside the home;
- extending access to social displays and journal applications to wider sets of family members and friends;
- trending social engagement with other health indicators and contextual factors;
- modeling trends in interpersonal communication, such as whether social overtures are initiated or received;
- modeling expansion and pruning of social networks over extended time periods;
- adding annotation tools to help individuals track subjective social satisfaction; and
- creating interactive displays that invite users to map out ideal social networks and periodically compare them with sensor-based depictions.

An ongoing challenge is to embed multiple value propositions in the same tools. Our findings supported expectations that adult children need tools that can help them manage their own lives as well as those of their parents. In the spirit of embedded assessment, these applications can become increasingly diagnostic and assistive over time. □

### Acknowledgments

I thank current and former colleagues at Intel, particularly Tim



Brooke and Jason Cassezza, who designed the social-network visualizations; Jeana Frost, whose probe studies influenced the design concept; and the former Proactive Health team directed by Eric Dishman (Jay Lundell, Terry Dishongh, Brad Needham, Kevin Rhodes, and Steve Agritelley).

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