



## Everyday Patient-Care Technologies for Alzheimer's Disease

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**A**lzheimer's Disease International estimates that more than 35 million people worldwide are living with Alzheimer's disease or a related dementia, and that number is expected to double in the next 20 years.<sup>1</sup> Improving home and community-based coordinated care is critical to mitigating Alzheimer's effects on individuals and families and to reducing mounting healthcare costs.

An integral part of this evolving care model is new technologies—particularly pervasive computing systems, such as mobile devices and systems for telemedicine, home monitoring, ambient assisted living, social networking, and informatics. Such systems can help identify individuals at high risk of developing Alzheimer's. They can also indicate advanced treatment and care-delivery options for those living with the disease, improving their quality of life by allowing them to maintain their independence and continue living at home.

Recognizing the importance of technology development, the Alzheimer's Association partnered with Intel back in 2003 to establish the Everyday Technologies for Alzheimer's Care (ETAC) initiative, which includes a grant program and an annual symposium for leading aging-health technology researchers. The ETAC grant program supplies three-year awards of up to US\$200,000, supporting research

projects aimed at improving the quality of life for Alzheimer's patients and their caregivers through technological solutions. Since the program's inception, the Alzheimer's Association has awarded nearly \$6 million to 30 related research projects internationally.

In addition to financial support, the Alzheimer's Association has stimulated collaboration and scientific advancement by bringing together leading researchers developing technological approaches targeted at preventing and treating Alzheimer's disease. This year, it collaborated with the International Society to Advance Alzheimer's Research and Treatment (Istaart) to organize the first Technology & Dementia Symposium at the 2013 Alzheimer's Association International Conference in Boston. Here, we present some of the projects discussed at the symposium, which addressed early diagnosis, monitoring, treatment, and assistance.

### DIAGNOSIS AND MONITORING

Without a single test that can demonstrate whether a person has Alzheimer's, obtaining a diagnosis can be a long and difficult process. Early detection and diagnosis empowers individuals with cognitive and functional concerns and their care partners to learn about management options, identify risk-reduction strategies, and obtain treatment to slow the decline. Furthermore, early diagnosis might allow the

individual greater participation in medical, legal, and financial decisions or even participation in a clinical trial. However, diagnosis can be complex due to the heterogeneity of symptoms, often requiring exhausting batteries of neuropsychological testing. Two promising approaches presented at the 2013 Technology & Dementia symposium focus on identifying early patterns of biological and behavioral changes associated with early-stage Alzheimer's.

One promising approach, developed by John Houde at the University of California, San Francisco, is the implementation of technology to detect voice responses to auditory pitch perturbations, such as changing the sound of your own voice. Typically, perturbing the sound of your voice results in a compensatory pitch change in voice response; however, damage to the white-matter tracts, linking auditory and speech production networks in the brain, alters compensatory responses to feedback perturbations.<sup>2</sup> This approach is supported by preliminary work demonstrating that individuals with Alzheimer's have a diminished response amplitude and slower adaptation. Considering that the hardware needed to implement a pitch perturbation diagnostic tool is currently available in smartphones and tablet computers, this is a promising approach toward developing a low-cost, noninvasive tool

that might help identify individuals in need of further evaluation.

Another approach is to apply new technologies to standard cognitive testing instruments, such as the Clock Drawing Test. In the CDT, the individual is asked to draw a clock face with the hands indicating a specific time, and the final drawing is rated by an assessor for errors. Randall Davis at the Massachusetts Institute of Technology and Dana Penney of the Lahey Clinic have developed a package using a digitizing pen and paper system to capture these errors and provide metrics of hand kinematics in producing the drawing.<sup>3</sup> These sensitive movement metrics, such as pause times at critical points in the drawing, potentially indicate deficits in movement planning that might be able to distinguish between healthy and pathological aging. Furthermore, the simplicity of the task and the low-cost digitizing system might be conducive to common clinical use, possibly providing data not previously captured by a physician or test administer.

To complement technological advances in developing diagnostic tools, the symposium highlighted projects aimed at monitoring everyday behavior to continuously assess functioning, such as functional mobility. New ambient electronic sensing systems embedded into living spaces are being developed to continuously monitor movements in the home and detect events that might trigger the need for emergency care. For example, people with dementia have two to four times the risk of falling compared to those with no dementia,<sup>4</sup> leading to a higher incidence of traumatic injuries.

These statistics prompted Victor Hirth, from Palmetto Health, and Juan Caicedo, from the University of South Carolina School of Medicine, to develop a fall-detection system based on building vibration patterns associated with fall events.<sup>5</sup> Similarly, at Portland State University, a research team led by Eric Wan is developing a new low-cost system to localize individuals based on a small network of radio-frequency emitting modules attached to the walls.<sup>6</sup> By analyzing

signal dispersion in the network, the system can capture movement indices, such as gait speed, and potentially detect falls. These types of technology tools might be beneficial in triggering emergency response situations for the aging population and in identifying individuals at risk for developing dementia.

Tapping into the ubiquitous mobile phone market, researchers are also monitoring changes in an individual's daily activities outside the home using GPS technology. For example, Stephen Bonasera and his colleagues at the University of Nebraska demonstrated their application of smartphone GPS to measure *life space*—that is, the size of the geographic territory in which an individual moves within his or her community. Life space, which is a strong indicator of physical and cognitive functioning,<sup>7</sup> is typically measured in an interview-based assessment, which can be unreliable or difficult for people with amnesic dementia to complete. GPS systems could eventually be scaled to large studies, providing information on how a particular intervention affects an individual's daily life. Or, such systems could collect data and send it to the physician, who then might adjust the treatment accordingly.

## TREATMENT AND INTERVENTION

Researchers are also developing technologies to improve current therapies and explore new treatments—such as art-based therapy. Case reports from trained therapists suggest that art projects can provide a valuable outlet for expression for people with varying stages of dementia, offering a creative activity that fosters engagement.<sup>8</sup>

With their ETAC award, a team at the University of Waterloo, led by Jesse Hoey, collaborated with a group at the University of Toronto to develop a large, multitouch tool in the form of an artist's easel for trained art therapists when working with people with dementia (see Figure 1). The device lets art therapists create customized painting and drawing screens to accommodate specific client



**Figure 1.** The epad—a large, multitouch tool in the form of an artist's easel for trained art therapists when working with people with dementia.

needs, selecting different tools (such as a paintbrush), colors, sounds, and animation. An artificial intelligence program runs behind the client interface and employs audible and visual prompts to reengage a client that becomes disengaged, a common issue for therapists. In initial studies with small populations, therapists were enthusiastic and considered the interface fairly intuitive; however, the prompting system to promote engagement was underutilized.<sup>9</sup> Current work is aimed at integrating affective (emotional) reasoning in a redesigned version of the application that runs on a standard multitouch computer. This affective intelligence will let the device better match its interventions to particular users and therapists.

The Oregon Royal Center for Aging and Technology, a consortium established through funding from the National Institute on Aging at the National Institutes of Health, has developed multifaceted

interventions that incorporate principles of health behavior change and provide continuous monitoring and care, delivered remotely in the home.<sup>10,11</sup> Modules have been developed for cognitive exercise, physical exercise, sleep management, and socialization, with each module incorporating both assessment (home monitoring and self-reporting) and coaching. The modules are designed for a single coach to work with many individuals, using different approaches for each patient depending on the activity, goals, and patient's willingness to share data. The research team, with support from an ETAC award, tested the system with 20 participants and is working to adapt the system to other neurological disorders (such as depression) and address different circumstances related to potential international collaborations that will implement and evaluate novel interventions.

### PROVIDING ASSISTANCE FOR ACTIVITIES OF DAILY LIVING

Intelligent technologies, such as Coach (Cognitive Orthosis for Assisting aCtivities in the Home), can help people with dementia complete activities of daily living (ADLs), depending on the person's level of need. Through funding from ETAC, Alex Milhailidis and his colleagues have demonstrated the Coach system's potential in supporting independent hand-washing among participants with moderate dementia in a pilot study conducted in a long-term care facility.<sup>12</sup> Currently, the research team is testing the cognitive orthosis concept using social robots to help people with dementia across other ADLs, such as making a cup of tea. Early results indicate that participants are open to robotic assistance and accept the robots' potential roles as aids and social companions.

Although many people with dementia usually require the most help with dressing, no assistive technology devices have been developed to tackle this issue. Diane Mahoney, from the Massachusetts General Hospital Institute of Health Professions, and Winslow Burseson, from

Arizona State University, have designed Dress (Develop a Responsive Emotive Sensing System), a system that combines context-aware computing with motivational counseling to provide dressing assistance. The Dress system employs a five-drawer dresser with an iPad on top and iPhones on each drawer to provide visual and audio cues to the user as needed. In addition, the user wears a wristband that monitors skin conductance as an indicator of frustration to warn a caregiver that further assistance might be required.<sup>13</sup> Mahoney and Burseson are further refining the technology and its scripting and cueing aspects.

Alzheimer's patients—presumably due to stress and anxiety about their ability to cope with everyday activities—often exhibit problematic behaviors that are highly stressful for caregivers, such as wandering and repetitive questioning. A group led by two of us (Jesus Favela and Jesse Hoey) is developing external memory aids to improve situational awareness and decrease stress on both elders and caregivers. Initially focusing on the problem of wandering, the team collected field data using InCense, a toolkit that uses GPS, Wi-Fi, an accelerometer, and near-field-communication tags to capture data about location and activity. Data from the field study was used to develop an activity recognition algorithm that displays situational information and provides reminders or suggestions to the patient over a smartphone, desktop computer, or tablet computer. Currently, the system is being tested to determine its effect on reducing anxiety and problematic behaviors in people with dementia and reducing the burden for caregivers. Furthermore, the team is using the data they've collected to develop an ontology of problematic behaviors and ambient-assisted interventions that might be helpful in addressing these behaviors.<sup>14</sup> For example, a prototype application called LaCasa aims to assist a person who seems to be wandering.<sup>15</sup>

As technologies are developed to help people with dementia, it becomes increasingly important to study factors

influencing adoption and long-term use. A group led by Chris Nugent from the University of Ulster in Northern Ireland is studying the predictor variables that influence adoption, including physiological, social, dietary, and lifestyle factors. The group is also studying functional, psychiatric, medical, and pharmacological histories; genealogical, medical, vital, and demographic records; and technology readiness. Using information from the Cache County Study of Memory in Aging<sup>16</sup> and the Utah Population Database,<sup>17</sup> this research aims to generate intuitive and easily understood prediction models that healthcare providers can use to determine which technology tools are best suited for individuals with memory loss.

**T**he impetuses to develop technology to assess, treat, and assist people with Alzheimer's and related dementia is clear, and the potential contribution of pervasive technologies is promising, but many challenges remain.

First, the path to the market remains unclear, with few companies eager to translate research findings into clinically relevant tools or to invest in the large trials required to prove the effectiveness of such technologies. However, the active participation of industry representatives at the symposium, the growth of mobile technology partnerships in Alzheimer's research, and increasing industry awareness of the positive effects of behavioral interventions are all healthy signs.

Second, although the emergence of pervasive technology continues to expand in reach and sophistication, designing technology for users exhibiting a wide array of cognitive, emotional, and physical disabilities remains a top priority. The heterogeneity of user capabilities and backgrounds highlight the need for systems that are adaptable, contextually appropriate, and employ multiple sensing modalities.

Furthermore, there's a growing understanding that combating apathy

is a key factor for effective intervention. Designing technology that fosters and sustains user engagement by striking the right balance between familiar and novel experiences remains a challenge for researchers. Rapid changes in the marketplace present another barrier, because rapid obsolescence of technologies makes it even more difficult to conduct technological intervention-based trials over several years.

Finally, there are also no standards in the community with regard to harmonization of research questions and outcomes, including quality of life measures. However, Istaart formed a Technology Professional Interest Area to examine these barriers and develop consensus around standards and the sharing of technical resources. The symposium will continue to provide a forum for bringing together a diverse group of investigators to build unified approaches to confront these issues. ■

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