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University of South Florida

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College of Behavioral and Community Sciences

The College of Behavioral and Community Sciences enrolls nearly 2,200 students and includes the Departments of Aging and Mental Health, Child and Family Studies, Communication Sciences and Disorders, Criminology, Mental Health Law and Policy, and Rehabilitation and Mental Health Counseling as well as the School of Aging Studies and School of Social Work. In addition, the college includes the Louis de la Parte Florida Mental Health Institute, a research, knowledge dissemination, and policy institute with a special focus on mental health and substance abuse.

Louis de la Parte Florida Mental Health Institute

The Louis de la Parte Florida Mental Health Institute at the University of South Florida has a mission to strengthen mental health services throughout the state.

The Institute provides research, training, education, technical assistance, and support services to mental health professionals and agencies as well as consumers, consumer organizations, and behavioral health advocates statewide. At the state level, the Institute works closely with the Departments of Children and Families (DCF), Corrections (DOC), Elder Affairs (DOEA), Education (DOE), and the Agency for Health Care Administration (AHCA), as well as with members and staff of the State Legislature and providers of mental health services throughout Florida.

**Florida’s Emergent
Gerontechnologies**

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Executive Summary

This document describes emerging gerontechnologies that will likely be available to the elderly in future years. Gerontechnology is an integrative discipline that examines the impact of technology on the elderly as it relates to health, housing, communication, transportation and work and leisure. Communications technology must play a key role in any future technologies serving the elderly, a fact that became abundantly clear as this review progressed.

Information technology can be especially useful in supporting the frail elderly and persons with dementia in both home and institutional settings. Besides describing that potential, significant attention is devoted to outlining communication between older persons and machines including robots and other adaptive devices. This is where contemporary research is making the greatest strides.

Emerging gerontechnologies can play a major role in helping the elderly maintain independence and delay entry into expensive nursing home facilities, and Florida's policy administrators must be sensitive to its potential. Today's technologies are not only more reliable than their predecessors; they are smarter and can perform critical therapeutic functions. One example involves the ability to remind elders who may be suffering the effects of early stage dementia to take their medication. Suitable technology may be embedded in household items, automobiles (to help disoriented drivers proceed safely to their destination), and other venues. The same technology can also objectively assess when becoming lost in familiar surroundings is frequent enough to require the individual to stop driving. Relevant information can be automatically reported to the elder's family or physician at their discretion.

Clearly, this "brave new world" offers policymakers a possible option to improve elder care and enhance public safety, but serious ethical issues must also be considered. While this manuscript describes some technologies that are not yet ready for public consumption; many are currently available to interested caregivers and insurers.

Background

In this report, a specific class of emerging technologies is evaluated for their long and near-term potential for improving health and mental health service availability to the elder citizens of Florida. The degree of cost reductions gained through applying a specific class of “Gerontechnologies” is also examined. Specific (though not exclusive) attention was focused on applications such as “Smart Houses”, electronic reminders for taking medication, smart transportation systems, location-based health and mental health services, radio frequency identification devices (RFID), telemedicine alternatives, robotic assistants, and systems that manage persons with dementia who wander while living at home.

Study Issues/Hypotheses

The research questions driving this review were:

1. What technologies are currently under development?
2. What technologies are now commercially available?
3. What technologies are only in the experimental stage?
4. How mature is a given technology?
5. How well can a given technology interface with other emerging technologies to enhance systemic efficiency (e.g. electronic medical record)?

Methods

Several strategies were employed in preparing this report. Our research utilized bibliographic databases, citation databases, and table of contents services to provide as comprehensive a review as possible. Bibliographic databases (indexing and abstracting databases) proved inconsistent because they do not index all journals cover to cover. Coverage can range from as little as one article per journal title to all special topic articles in a special topic issue. We therefore turned to more inclusive sources such as citation databases and table of contents services.

This broadened our scope of research, and the following were accessed toward that end: Communications Abstracts, Engineering Village, IEEE Xplore, INSPEC (ScienceDirect), Health and Safety Science Abstracts, Institute of Physics electronic journals, Lecture Notes in Computer Sciences, Mechanical Engineering Abstracts, National Technical Information Service, Nature Publishing Group, Risk Abstracts, and Wiley Interscience.

In addition to these discipline-specific databases, a number of aggregator databases, (e.g. Expanded Academic Index) were also reviewed. Other pertinent materials were found in grey or fugitive literature such as conference proceedings.

The National Agricultural Library’s databank (including Agricola and the Rural Information Center) was helpful in our examination of rural and frontier areas.

The impact on ethnic populations was determined through data obtained from a number of sources, including Chicano Database, CIAO, and Ethnic Newswatch. Other data related to the Caribbean region, Latin America, and South America was secured through BIREME and PAHO (Pan American Health Organization).

Information was also gleaned from official reports and other publications through the federal Government Accounting Office (GAO), U.S. Administration on Aging (AoA), Agency for Healthcare Research and Quality (AHRQ), Department of Health and Human Services, Substance Abuse and Mental Health Services Administration (SAMHSA), Bureau of Economic Analysis (BEA), Agency for Health Care Administration (AHCA), the Florida Office of Program Policy Analysis and Government Accountability (OPPAGA), and others. We also searched table of contents services (e.g. Current Contents) and citation databases (e.g. Web of Science). It is ensured that critical articles were not missed and that trends and trajectories in gerontology and technology could be fully captured through citing relevant passages.

This review begins with a critical evaluation of each emerging technology and its potential impact on the delivery of health services to older Floridians. These are then compared and contrasted with one another. Their relative merits are analyzed according to the specific research questions outlined above.

Discussion

Florida's potential to be a national leader in Gerontechnology

Elderly residents comprise 17.6% of Florida's population, among the highest proportion of any state in the country. The national average at 12.4% roughly corresponds to the overall proportion in the South as a whole (Campbell, 1997). Meanwhile, the statewide percentage of elderly residents is expected to rise to 26.5% by 2025. A large share of these individuals will have migrated to Florida from other states, while others will come from outside the U.S. Furthermore, Florida's postwar Baby Boom generation is rapidly approaching retirement age (which is also the case throughout the US).

As elderly residents grow older, responsibility for their care will fall to family caregivers and private insurers along with federally funded Medicare, and Medicaid programs which receive mixed federal and state support. A progressively smaller workforce will carry the additional caregiver burden, while elder care funding will require an increased proportion of federal and state's budgets (Uhlenberg, 1992) (Hobbs & Damon, 1996). The US Census estimates that the national old age dependency burden (i.e. the ratio of the number of persons older than 65 to those younger) will increase from 21.1 to 28.4 by 2020. However the old age dependency burden for Florida in 2000 (30.8) was already higher than the 2020 national average. It is projected to increase still further to 39.6 by 2020.

However, the scenario for the US pales in comparison to Europe (Butler, 1997). In fact, elderly residents may soon comprise over 22% of all Europeans compared to 12.4% of Americans

State government has responded by considering changes in Medicaid program eligibility, provider reimbursement, and experimenting with waiver programs designed to use scarce fiscal resources more efficiently. These new policies can attain substantial improvements as long as they are based on careful research that

identifies how precise adjustments can be made in eligibility criteria and service delivery. However, policy changes alone cannot grow legions of new caregivers overnight nor create large new funding streams to provide for the care that retiring Baby Boomers will require. Emerging technologies may help fill this widening gap in healthcare coverage for the nation's seniors.

Driving functions pushing development of Gerontechnologies – the Baby Boom and the explosion of new technology

America's long love affair with technology can be traced to the Industrial Revolution. It became firmly ensconced in our culture shortly after the First World War as a wealth of new technologies became accessible to the consumer market (Pursell, 2007). Technologies that originally served a military purpose during World War II (e.g. radar, wireless communications, computers and cybernetic control systems) were adapted for civilian use in the 1960's, 70's and 80's. These led to consumer goods such as microwave ovens, wireless telephones, personal computers and (most recently) as personal automata (robots, etc.).

As these technologies matured, their usability and appeal expanded dramatically because of two factors: improvements in their general capabilities and the addition of "embedded intelligence" in the machines themselves to improve their adaptability. Embedded intelligence extends the functionality of a given device by making it "smart" (i.e. able to learn the preferences and normal routines of their user) (Aarts & Marzano, 2003). It can thus enable seniors to maintain their independence longer and thereby forestall the need for expensive nursing care, as illustrated later in this manuscript. The pace of technological improvement is especially encouraging in this regard. Moore's Law (Hiremane, 2005) predicts a doubling of computing power approximately every 2 years, a target that has largely been met thus far. When applied to concepts such as "Ambient Intelligence" (Barger, Brown, & Alwan, 2005) or as "Ubiquitous Computing" (the notion that thinking machines can be embedded everywhere throughout the everyday environment) (Coyle, Neely, Nixon, & Quigley, 2006), the positive implications are tremendous.

One outgrowth is a gradual decline in computing hardware costs, which enables manufacturers to incorporate new "smart" features into formerly "dumb" devices and provide an edge over their competitors by installing ever-improving integrated circuits.

Let us consider the lowly vacuum cleaner as an example of how improving technology carries exponentially greater benefits. Since the ability of an elderly person to maintain a clean living environment can help determine whether they can function independently, using a vacuum can be critical. While the State of Florida now provides Medicaid funding for chores to be performed on behalf of elders who cannot perform these functions themselves, the day may come when these services are no longer available.

When rudimentary embedded intelligence is placed in a vacuum cleaner, it is able to automatically clean a greater variety of floors. Its power consumption is managed more efficiently (thereby qualifying as a "green technology"). It can also

filter airborne particulates more effectively, a point that is particularly significant to people with COPD. By informing the user when it is time to replace the dirt collection bag, this “smart” vacuum would further improve household sanitation.

However, some products go much further and are entirely automated so that they can be operated with very little intervention. For instance; the Roomba robotic vacuum cleaner can continuously perform basic housekeeping and cleaning tasks autonomously for weeks at a time (see <http://www.irobot.com>). Some Roomba models can wash tiled floors and detect the difference between a hardwood floor and a tile surface. They are capable of automatically applying different cleaning techniques and chemicals according to the particular type of floor. Thus, a formerly simple single-purpose device can now be programmed to perform unattended tasks based on specific physical and cognitive limitations while requiring very infrequent maintenance. Ironically, the Roomba’s development team originally was trying to design a smart wheelchair capable of avoiding obstacles for its user. A successful prototype was built; but liability concerns terminated the project. The IRobot team then modified the technology to create the popular Roomba.

Meanwhile, the effort to develop intelligent wheelchair prototypes is still progressing (Lankenau & Roefer, 2000). One objective is to compensate for the user’s cognitive decline by creating fully autonomous wheelchairs (Cortes et al., 2007). In fact, robotic wheelchairs that can climb stairs are already available to the general public (see Johnson & Johnson, Inc.’s <http://www.iobotnow.com> subsidiary for specific details).

This review touches on the five major domains of Gerontechnology (housing, health, transportation, work & leisure, and communications) where new technologies can serve the elderly (Fozard, Rietsema, Bouma, & Graafmans, 2000). In fact, technology now being developed can actually be applied in multiple domains. For example, new cellular telephone systems (communications) can record and process realtime physiological data (health) from devices that elderly persons wear while living at home (housing). These devices use Global Positioning Systems (GPS) to fix the information to the location where it was collected, which might be a moving vehicle (transportation). As a result, an elderly person may be able to continue living at home instead of transferring to an assisted living facility or nursing home. The biomedical monitoring capabilities of these devices potentially equal or exceed that offered by more expensive alternatives such as traditional Holter cardiac monitors. Because communication technologies facilitate overlapping benefits, our initial focus turns to them.

Communications & Wireless Technologies

Motorola introduced portable telephone technology to the public in October 1946. Early portable telephones used large power-hungry electron tube circuits which occupied most of a vehicle’s available trunk space (Motorola, 2008). Their relatively short range transmissions limited their use to major metropolitan areas with strategically placed antennae; and their interface was a common handset and rotary dial. By the 1980s, technological improvements led to a walkie-talkie

shaped device weighing between one and two pounds, with a touch tone keypad replacing the rotary dial. Further miniaturization and the introduction of cellular based services by Motorola and others have enabled users to have international coverage, hours of conversation time, sophisticated features never conceived of by the originators, and a telephone that resembles a key fob. Indeed, it is the additional cellular telephone features that may offer the most hope of sustaining independent living for the elderly in Florida and elsewhere.

It is clear that having telephone access improves one's personal sense of security and wellbeing by connecting people to critical health services that include ambulance, fire & rescue, and their personal physician. Meanwhile, some professional health monitoring services (e.g. LifeAlert) have been partially supplanted by the ability of cell phone users to summon emergency assistance by calling 911. As cell phones become increasingly ubiquitous, this trend will likely intensify. This relatively recent development stems from the federal E911 Telecommunications Act of 1996 (Handler, 2005). However, 911 access is currently hampered by the fact that not all cellular telephones manufactured today comply with E911 regulations, even after twelve years. Once this is resolved, and as the critically important integration of cellular telephone with global positioning system/geographical information systems (GPS/GIS) becomes prevalent, E911 services can be fully accessible. This will be discussed further in the following section.

The outdoor location of commercially available cellular telephones is now detectable from within +/- 7 meters, or roughly 25 feet. Their embedded intelligence can execute programmed instructions on the basis of their location because of improved computing and storage capabilities (Patterson et al., 2004).

The most advanced cellular telephones can store in excess of one gigabyte of data or software and compute at a level that rivals Pentium workstation performance.

They arguably qualify as the next generation of networked computers because of their connectivity to international telecommunications networks, the Internet, and most recently to local ad-hoc Bluetooth or ZigBee networks (Marshall, 2006). Like computer workstations, cellular telephones currently download and execute programs, automatically patch their own operating systems from the network as required, exchange data with remote computers and other cell phones and wireless devices, and update databases. They can also act on specific information either generated by the user or sensed in realtime from their local environment. Bluetooth networking capabilities allow cellular telephones to directly command and control commercially available robots, the simplest of which can be programmed by a child (see <http://www.lego.com> for a description of the NXT robot which can be guided by a telephone's keypad).

The development of Apple's iPhone has particularly exciting ramifications for the elderly (see <http://www.apple.com/iphone>). It supports voice calls but also has tiny accelerometers to measure minute changes in movement and orientation of the telephone. These accelerometers are designed to make the display and keypad rotate to accommodate the user's preferred viewing angle. However, the accelerometers are also addressable by any other software running

on the telephone. For instance, an experienced programmer in the healthcare profession can write software to address the specific needs of an elder who has gait or balance problems (Greene, 2008) (Greene, 2007). As a result, a healthcare monitoring system within the Iphone could use these accelerometers to detect gait disturbances that can characterize various movement disorders including Parkinson's disease and wandering in persons with dementia. This could serve as an early warning system for functional decline by providing regular updates to a health services network utilizing electronic medical records. Numerous telephone manufacturers besides Apple (e.g. Motorola and Nokia) have cellular telephone operating systems that can be customized according to user needs. A Linux operating system variant is currently available for home users who wish to experiment with the telephones as mobile service delivery devices. Microsoft offers a telephone operating system which supports its .Net programming framework, and allows access to low level functions in the cellular telephones (see <http://www.microsoft.com/whdc/connect/wireless/default.mspx> for more details).

A growing body of research, which includes computing, wireless communications and biomedical engineering, points to an expanding role for wireless communications devices in addressing cognitive and movement problems in persons with disabilities. An emergent field called "Cognitive Orthotics" (Rudary, Singh, & Pollack, 2004) applies networked computing in a rehabilitative medicine, psychology, and biomedical engineering context. Cognitive orthotics supports the independence of persons with cognitive limitations or disabilities. It provides realtime machine intelligence-based services that detect a person's cognitive challenges and correct them on the spot (Philipose et al., 2004). The cellular telephone is a preferred development platform for many scientists and engineers exploring ways to provide new services to the elderly because it is ubiquitous, global, inexpensive, flexible, and durable. Furthermore, an extremely active development community is continually improving the telephone's technological capabilities. Palm Pilot technology has also been used in cognitive orthotic service development because of its modular characteristics and its ability to interface with a wide variety of peripheral devices (Kautz, Arnstein, Borriello, Etzioni, & Fox, 2002), though its development is evolving at a much slower pace.

The areas in which these portable smart wireless devices can eventually be applied in cognitive orthotics include:

- The detection of wandering in persons with dementia (Miskelly, 2005) (Miskelly, 2004)
- Assisting persons with dementia and/or developmental disabilities in using public transit (Aguilar et al., 2007)
- Reducing the incidence of falls among persons having cognitive impairment (Vehkaoja et al., 2007)
- Providing a navigational aid for visually impaired persons (Belongie, Belongie, Malik, & Puzicha, 2002)
- Providing technological support to remediate memory impairment in brain injury cases (Wilson, Emslie, Quirk, Evans, & Watson, 2005) (Berry, 2007)

In many of these service applications, the cellular telephone or other portable wireless device's software constructs a mathematical model over time of the normal behavior of the person wearing the machine. These technologies are largely still in the experimental stages but offer significant promise as telephone computing capabilities increase. They may eventually monitor the person's location and the objects they interact with. For example, raw data may one day be processed by onboard software and combined with data from the machine's GPS chipset, accelerometers, and/or associated wireless Bluetooth enabled devices (e.g. wireless microphones, hearing aids, electronic compasses that provide information on the elder's orientation and heading). Possible applications for monitoring deviations from the person's predicted normal performance include a coffee pot, a refrigerator, or other appliances (Choi, Krause, Imperio, Macchio, & Rill, 2005). These deviations can indicate breakdowns in the elder's normal routine that either warrant closer examination or direct intervention. In fact, the device itself may furnish an appropriate intervention contingent based upon the nature of the deviation (Philipose et al., 2004). It may be possible for an intelligent appliance or other product to render health and hygiene assistance in gradations ranging from minimal audible prompting ("Remember to wash your hands!") (Hoey, Poupart, Boutilier, & Mihailidis, 2005) to notifying a remote caregiver that assistance is required because normal toileting behavior is not occurring. The machine could even be programmed to dial 911 if the elder has not moved for an extended interval or shows signs of significant decline.

Currently, telecommunications technology is being effectively employed as a reminder for patients to take medications on schedule. Biem, Turnell and D'Arcy (2003) reviewed the literature concerning the use of computer based telephone reminder systems for care delivery. They concluded that persons having chronic medical conditions are more likely to comply with medication schedules through computerized reminders. The authors also concluded that the systems had significant unrealized potential as a valuable supplement (though not a substitute) for medical care. Other research of the literature focused on interactive voice response systems (IVR) and the data on factors affecting their usefulness. One researcher found that the development of ergonomically sound guidelines for IVR has been slow and often inconsistent (Dulude, 2002). In Dulude's research, 22 young (18-27 years) and 22 older (65-86) women sought information from six existing systems—Regional Municipality, Canadian Airlines, Income Security, Statistics Canada, AccuRate Foreign Exchange and United Airlines (the only system that allowed for voice input instead of keystrokes). Each system was measured for its perceived usability, as well as by the success rates for completing assigned tasks. The median number of successes by the older group was 2.8 vs. 5 for the younger; the comparable percentages of participants succeeding on at least 5 of the 6 tasks were 32% and 82%. The number of successes for each system varied widely, more so for the older adults. The two groups were equally successful using the Income Security system, the system on which performance was best. Older adults were much less successful with the United Airlines voice activated system. Younger adults gave higher usability ratings to all systems except the Income Security system, for which the rated usability was the same

in both groups. Older adults experienced much greater difficulty in following prompts, recovering from an error, and in being confused about a specific task. Older adults also encountered more numerous problems in using a variety of existing telephone menu systems to accomplish a transaction or reach a human respondent (Czaja & Sharit, 2002). Of various interventions explored, providing older adults with a graphic depiction of the menu was more effective than providing a visual display. Slowing the speech rate did not improve the performance of the older users.

Meanwhile, Gardner-Bonneau (1992, 1999) and others agree the memory burden of menus should be limited to no more than three levels, and no more than four choices per level. The ability to skip over spoken alternatives is also recommended. Error messages should never blame the caller and should provide explicit information for completing the call or reaching a human operator.

Ala, Berck, and Popvich (2005) studied the ability of outpatients with Alzheimer's disease or mild cognitive impairment (measured by MMSE scores) to use a telephone to call for help in an emergency. Participants were given a choice between calling a standard emergency number—911 or 0— or a specified 7-digit number written on a piece of paper. Performance was better in all ability groups when the number was provided. Success rates increased from 0 to 100% as MMSE scores rose from 0-9 to 26-30 when the number was provided. The corresponding percentages increased from 0 to 76% as MMSE scores rose from 10-15 to 26-30. Failure to remember the standard emergency number was the major limiting factor in the successful use of the telephone by these patients. Similar conclusions were reached in a Swedish study (Nygard & Starkhammer, 2003).

While this application is still being developed, two-way video capabilities in the newest cellular telephones open avenues for providing imitative behavioral prompts to people who might have forgotten an important step in a chain of ADL behaviors. For example the desired behaviors could be shown in a video triggered by a failure to perform the ADL. Ideally, seeing the specific action will cause the person to duplicate it in their current environment. It could be verified by the phone's video camera and observed by a remote caregiver or even through a machine based video verification algorithm. The phone might eventually enable an individual's health status to be assessed and/or their wounds managed from a remote location assuming there is sufficient camera resolution and bandwidth available for uploading the images. This latter option will be discussed in greater detail in the section on the implication of telemedicine. However, only Europe and Asia currently provide sufficient bandwidth to their 3G (3rd Generation) telephone users so that two-way video (Zhao, 2002) would have sufficiently high resolution. The US is expected to follow suit with its own 3G system in the coming years.

GPS/GIS Systems

Global positioning systems (GPS) owe their origin to Cold War research (Parkinson & Spiker, 1996) into how ship navigation could become as precise as possible. GPS devices first found civilian application by improving ship and aircraft

navigation, and are now used in private vehicular and personal handheld wireless navigation devices such as cellular telephones and portable GPS devices (e.g. Tom-Tom). A network of geosynchronous satellites employs highly precise signal timing so that a GPS can establish a 3-D positional fix to within approximately 25 feet for civilian systems, though military grade systems are considerably more precise. The accuracy of the fix depends upon the number of satellites viewable by the receiver on the ground. Four viewable satellites provide the most optimal fix, but three satellites will generate sufficiently reliable data for most purposes. GPS accuracy varies according to the degree of global satellite coverage, with some regions having much less than others. Recently, the European Union (EU) introduced its competing GPS product called “Galileo” (Beidleman, 2005). It provides a more precise alternative to American GPS technology, and Galileo also promises superior global satellite coverage. New receivers for telephones and other wireless devices are being designed to use either GPS system interchangeably, or to enhance accuracy through combining the systems (Hein, 2005).

Gerontechnologies that use these GPS and Geographical Information Systems (GIS) require a high degree of accuracy so that appropriate (and often urgently needed) services can be provided to the elderly. European nations have more fully embraced gerontechnologies than the US because their geriatric populations are considerably larger (averaging 22% of their population compared to only 13% for the US), and because the EU has a smaller workforce to attend to the needs of its elderly. Consequently, the EU is investing significant resources into developing technologies that permit aging in place.

GPS systems are especially significant for a new class of “Location Based Services” (Schiller & Voisard, 2004) that provides cues to persons with cognitive disorders. It helps these individuals according to their location, the time of day, objects they interact with, or behaviors they are engaging in. The more accurate the GPS, the more precisely services can be delivered to relieve cognitive disorders. This is true whether the services involve critical 911 calls placed inside a busy shopping mall, or a reminder of where their regular bus stop is located. While a civilian GPS provides accuracy to within approximately 25’, a hybrid GPS variant (“Assisted GPS” or “AGPS”) found in many cellular telephones improves this accuracy to less than 10’ by triangulating ground-based cellular telephone towers with information from the satellite based GPS (Zhao, 2002).

A second factor driving the expansion of location based services is the explosion in GIS which has resulted in the proliferation of highly accurate maps of the earth’s surface (Fulcher & Kaukinen, 2004). Emerging technology allows the information to be manipulated with relative ease. The combination of highly accurate GPS satellite data and GIS mapping tools has enabled precise surveys of landforms, waterways, city boundaries, roadways, transit routes and population characteristics. These can then be integrated with census information or data from secondary sources such as Medicaid eligibility files or treatment data. This synthesis can produce customized “layers” containing information about available health and mental health services, nursing home and assisted living facilities in the area, and specialized information generated by the user’s research for the

express purposes of their application. For example, distributions of Medicaid beneficiaries using particular classes of services in specific regions could be plotted graphically as a layer, which complements a more conventional statistical analysis of the data (Fulcher & Kaukinen, 2004). This can then be merged with additional layers showing manmade and natural resources evaluated for their effect on service delivery. One of the most useful GIS features is how it precisely calculates driving distances and times from a patient's home to their service provider's door.

This allows an assessment of how these two variables impact a client's access to health care. It can also identify where healthcare resources can be located in rural areas to improve service access by minimizing transit times and distances.

Among academics, ArcGIS (an ESRI, Inc. product) is the most highly regarded Geographical Information Systems software package (ESRI, 2008). It successfully interacts with statistical software packages (e.g. SAS, SPSS) and its "StreetMap USA" algorithms analyze complex roadway networks to determine precise driving distances and times between multiple locations. ESRI, Inc. processes travel data for most Internet-based mapping resources including Maps.com and MapQuest.com. This company also serves federal agencies such as the Department of Homeland Security and the Department of the Interior.

The combination of GPS and GIS systems for personal transportation assistance has exploded in the past several years as these systems have been miniaturized and incorporated into motor vehicles. General Motors' pioneered its "OnStar" product to inform drivers of their location while in transit by using a human operator to relay near realtime data via the vehicle's built-in cellular telephone connection. More recently, the human operator has been replaced by machine-generated voices or realtime turn-by-turn instructions on the driver's video console (see http://www.onstar.com/us_english/jsp/index.jsp?seo=google_2008_OnStar_Upfront_-_OnStar_Make_-_OnStar_-_onstar for more information).

GIS technology can be especially beneficial to the elderly, since personal mobility is highly related to a sense of independence that is a predictor of their future health. (Community Mobility: Driving and Transportation Alternatives for Older Persons, 2006). Determining when early stage dementia makes it unsafe to drive is therefore no trivial matter. In some cases, becoming lost while driving may be sufficient to rescind driving privileges (Mann, 2006). Automated systems that provide gentle guidance to keep elderly drivers on course can prolong their ability to drive, and thereby delay their entry into assisted living facilities. However, they could also provide indisputable evidence that a person should quit driving by showing that they are repeatedly unable to navigate familiar roads (Philipose et al., 2004). It is noteworthy that this author was taken on a 77-mile ride across the northeast two years ago by a limousine driver who had previously sustained frontal lobe damage in a car crash. She relied exclusively on her GPS guidance system with an artificial voice (a Tom-Tom) to direct her to her destinations. The limousine driver indicated she would have had to retire from her profession had the device been unavailable, and referred to the Tom-Tom as "her best friend." It was so anthropomorphized that she had assigned a name

and persona to the device that complemented its synthesized female voice. Such is the value and desirability of these devices when they help persons retain their independence, and their importance should not be underestimated. As mentioned previously, this freedom comes with a price tag of increased surveillance that can provide evaluators with objective data documenting significant deviations from normally taken routes, and thus cause driving privileges to be rescinded.

GPS/GIS based guidance systems come standard on new luxury vehicles while portable devices (see <http://www.tomtom.com/> for more information) are available to all drivers. In addition, these devices are increasingly being found in handheld wireless devices and cellular telephones. It is worth noting that Apple's popular Iphone does not have native GPS capability but uses only cell phone towers to triangulate the user's position for rescuers. However, the Iphone can gain GPS functionality through the purchase of add-on technology.

There is also a market for GPS-based wireless devices as electronic tour guides for visitors to new cities and towns (e.g. Tom-Tom and Bar Z Adventures. See <http://www.barzadventures.com/> for more information). These devices can direct users to specific restaurants or unique attractions, and the phone's built in web browser may also enable them to purchase event tickets (e.g. Bar Z Adventures). Hence, it is possible to envision adapting these guidance services to meet the needs of persons with specific cognitive disabilities.

As mentioned earlier, many public safety and fire/rescue vehicles use an enhanced GPS/GIS system (including Assisted GPS or AGPS) on 911 calls with a locating capability significantly more accurate than the commercial standard of 25'. This improves 911 services by reducing search times for rescuers, and thus saves more lives. However, AGPS works only when a sufficient number of antennae can triangulate the caller's position. When these conditions do not exist, the GPS relies on satellites to supply data to rescuers. Under these circumstances, GPS positioning accuracy can be degraded according to the number of GPS satellites visible to the cellular telephone when the 911 call was initiated.

The GPS chipset will likely play a more critical role in the near future for elderly persons with cognitive impairment as Cognitive Orthotics research yields technological advancements (Pollack, 2005). Since programmers have recently gained access to cellular telephone internal hardware such as the camera and GPS chipset, their creativity can eventually produce improved ways to serve the growing number of elderly residents (Miskelly, 2005) (Aguilar et al., 2007) (Vehkaoja et al., 2007).

Computer Miniaturization

As the cellular telephone's computing capabilities have increased (and been made more accessible to programmers), users are able to tailor their telephone's operating systems to serve specific needs, and replace them with alternatives that better meet their needs if necessary. Cellular telephone technology is currently advancing at an explosive rate that even exceeds the computer industry as a whole. They now have mass storage measured in gigabytes and processor speeds approximating Pentium performance. They can send and receive streaming

video depending upon the network service provider's capabilities, and can simultaneously support multiple wireless network protocols. This technology enables a cell phone to not only communicate like traditional telephones but can also link them with other wireless devices such as hearing aids, computers and robots in their direct vicinity by using wireless protocols such as Bluetooth.

An emerging field of "Cognitive Radio" (Haykin & Haykin, 2005) seeks to connect cellular telephones with local wireless networks to find the most cost-effective communication choice. Many digital voice communications networks use Voice over Internet Protocol (VoIP) to support conversations at a distance.

The least expensive option often involves making a Skype connection between a corporate wide area computer network (see <http://www.skype.com>) and a conventional personal computer equipped with speakers and a microphone. A cellular phone embedded with cognitive radio software could automatically locate the most economical option without the user even realizing it. One possible scenario could be someone who is on a long-distance cell phone conversation as he enters a Starbucks, where free long-distance service is provided through its local area network (LAN). The phone's cognitive radio system then seamlessly transfers the call to the Starbucks LAN, which can represent a significant savings for as long as the user remained on the Starbucks network. The process is automatically reversed when the user leaves the Starbucks, and the call reverts to the original carrier at the applicable charge rate.

While adapting this technology to the health care industry may be cost-effective, other issues must be carefully considered in advance. Confidential patient information may not be secure on all private computer networks accessible through a cognitive radio equipped cellular telephone. Additional encryption protocols may therefore be required to protect sensitive information.

The same concerns exist when Skype connections are made to a computer.

The following web sites provide further details on technological advancements for specific wireless devices and telephones: Palm Pilot (<http://www.palmpilot.com/>), Blackberry (<http://www.blackberry.com>) and Iphone (see <http://iphone.rdmplus.com>) Microsoft Windows operating systems and productivity packages consisting of MS Word, Excel and other applications (e.g. .Net, Linux, & Java) allow these and other wireless devices and cellular telephones to perform many functions once found exclusively on full-sized computers (<http://www.microsoft.com/windowsmobile/business/success/healthcare.aspx> provides more information about Microsoft's productivity software on handheld devices).

Indeed, as a technology the networked portable wireless device holds great promise for conducting services research as a data collection tool, as an informational resource for the user, and even as a personal navigation tool (Kearns and Fozard, 2007; see also <http://na.blackberry.com/eng/builtforblackberry/navigation.jsp>). Researchers in health sciences, engineering, and (most notably) computer science continue to actively explore how the wireless device's ability to perform highly complex functions can be adapted to their respective fields.

While wireless devices such as telephones continue to shrink in size and become more powerful, human limitations place external constraints on

the balance between technology and function. The lower size limit of these communications devices is dictated by the accessibility of their functions. Many elderly routinely complain that their access to cellular telephone functions is made more difficult by small keys, small display sizes, and poor font choices (Omori, Watanabe, Takai, Takada, & Miyao, 2002). They are also less likely to use text messaging features, since tiny keys make accurate operation of the keyboard difficult as manual dexterity declines. Poor interface design and the anxiety it creates have been cited as reasons that the elderly may be reluctant to adopt technology (Czaja et al., 2006).

The wireless industry will find it more difficult to make further size reductions until the potential of speech recognition interfaces is more fully realized (Sharit, Czaja, Nair, & Lee, 2003). Nevertheless, cellular telephone use among the elderly is increasing as carriers press to reduce the number of land lines into residences, and Americans embrace the additional flexibility provided by wireless communications devices. Computing technology use among the elderly in general has lagged behind that of younger persons due to cohort effects, the tendency by elders to continue to adhere to the technologies of their younger years (Fozard & Kearns, 2007), anxiety over the use of new technology, and declines in fluid and crystalline intelligence (Czaja et al., 2006). However, this trend is likely to change somewhat as people who are already familiar with computers, PDA's, and Blackberries become elderly themselves.

Microsoft is among those who recognize how these devices can potentially improve mental health service delivery. In the fall of 2007, the author attended a Microsoft-sponsored "Workshop on Assisted Cognition" at the University of Rochester. No fewer than 31 research teams from internationally recognized universities presented 14 talks and 25 poster sessions describing their research in wireless technologies to assist persons with autism, brain damage, dementia, and blindness and other sensory disorders. Unfortunately, Microsoft forbade the citation of any presentations or talks which occurred at the workshop.

However, Microsoft is developing SenseCam, a wearable digital camera designed to independently take photographs while it is being worn by dementia sufferers. SenseCam records what the person sees during the day as a series of still photographs (up to 30,000 on one SD-type memory card) which can be reviewed later. Its shutter is tripped by changes in light, infrared energy (body heat) and movement (through accelerometers). At the Rochester workshop, researchers who used this device claimed that people with dementia were able to retrieve memories when they were shown these images as prompts. Their experience indicates that SenseCam may have significant therapeutic value. For more information on the operating theory and capabilities of this device, please see <http://research.microsoft.com/sendev/projects/sensecam/>.

Traditional personal computing has also benefitted from rapid gains in processing power. The latest generation of personal computers is equipped with high-speed dual core processors that can process information much faster. However, their practical benefits are not yet fully realized because some current software is unable to take advantage of these enhanced processing capabilities.

Nevertheless, the added benefit of a large traditional keyboard and display increases the usability of web browsers, spreadsheets, e-mail and even video games by the elderly.

The Role of Computer Networks

New home personal computers have enhanced networking capabilities. They can potentially access over 1 Gigabit of information per second over their wired connection and 54 Megabits/sec. over their 802.11g wireless interfaces. While these values may seem extraordinarily high, Verizon is among the telecommunications carriers that currently offer more than 30 Megabits/second of IP-based fiber optic services to Hillsborough County homeowners via its FIOS (Fiber Optic System) program (see <http://www22.verizon.com/content/ConsumerFios> for more details). The firm is now extending these high bandwidth services throughout Florida. As this availability spreads, it opens up possibilities for delivering networked health and telemedicine services to elderly residents of underserved areas (Kearns and Fozard, 2007).

The Federal Communications Commission and the National Institutes of Health jointly presented its first set of national Internet2 Project awards in 2007 to states seeking to bring high bandwidth network access to facilitate improved health care in rural areas (see <http://www.fcc.gov/wcb/tapd/ruralhealth/>). Florida has received \$9,623,019 in startup funding through the “Big Bend Regional Healthcare Information Organization.” Lisa Rawlins, Bureau Chief, State Center for Health Statistics at AHCA manages the Florida initiative (McGill, 2007 [personal communication]). It involves creating a 1 Gigabit/second fiber optic network to link approximately 9 rural hospitals in 8 counties to the existing Florida LambdaRail infrastructure. Broadband wireless networks will eventually extend this capacity to community health centers and clinics. The objective is to improve patient care through disease monitoring and access to specialists, while also enabling access to distance education and other existing networks. As a result, it will notably improve access to healthcare, telemedicine, and Floridians’ electronic medical records. AHCA is releasing project funds to participating organizations in Florida as this report is being composed. Once the program moves from pilot funding to full-scale implementation, the rural healthcare telecommunications initiative will expand rapidly. As much as \$400M/year will be distributed to the states to facilitate completion of a national fiber-optic network toward this end.

Computer networks can efficiently store and distribute information among millions of individuals, as demonstrated by the dramatic growth of the Internet. One of its most common uses is by elderly residents who search the Internet for health information (Rideout, Neuman, Kitchman, & Brodie, 2005). Their interest focuses on the availability of new treatments, access to physicians, expected outcomes, and services covered by their health insurance program (Flynn, Smith, & Freese, 2006) (Demiris et al., 2007). Subscribers learn about changes in healthcare coverage and benefit schedules almost as they happen. Many Internet users communicate with their physicians and health service providers via e-mail; though

federal HIPAA regulations require that encryption protocols must be used when private health information (PHI) is transmitted. Research shows that at least some individuals who access healthcare services online have seen small but significant cost savings (Baker, Rideout, Gertler, & Raube, 2005). Meanwhile, consumer satisfaction with enhanced electronic medical record access is greater than that for traditional methods (Ralston et al., 2007).

Electronic Games and the Elderly

Playing electronic games online is increasingly popular among seniors, often with others at remote locations. Heretofore considered only the province of the young, researchers have found that many elders routinely enjoy using the Internet for a variety of recreational activities including games (Griffith & Fox, 2008). Cognitive stimulation from playing games has been touted by researchers as a means of forestalling dementia (Gamberini, Alcaniz, Barresi, & Fabregat, 2006). New products such as Nintendo's "Wii" (Nintendo, 2008) have added a physical exercise component that has made them very popular in nursing homes. For example, virtual bowling and golfing are two sports found to have great appeal among elderly nursing home residents. Elders can compete against friends in other areas of the country, in other assisted living facilities, or nursing homes by playing Wii games online. Researchers are exploring how to deliver health education through games that can be both challenging and fun for people who may find conventional learning to be more difficult. These games address issues such as maintaining a proper diet, counting calories, and staying physically active. Nintendo has claimed that its Brain Age game is an example of how gaming can improve cognitive functioning among seniors "Brain Age" (Nintendo, 2008). Some therapists have incorporated game interfaces into routine neurological rehabilitation technologies for patients suffering from a stroke or paralysis.

is is meant to increase electromyographic potentials in paralyzed muscle, provide graphic evidence of recovery efforts, and help to maintain attention and enthusiasm for the rehabilitative task. It also allows for the evaluation and comparison of therapeutic progress through the remote monitoring of patients via the network. The use of networks to provide advanced telehealth care is the subject of the next section.

Telemedicine

The advent of low cost broadband internet service to the home has brought significant opportunities to improve telemedicine delivery. For many years, the only telemedicine video transmissions were from one formal care environment to another via Integrated Services Digital Network (ISDN) over conventional telephone lines. ISDN worked well but was expensive, and usually limited to bandwidths of 128 Kb/sec over two channels (though multiple channels could be combined to produce higher bandwidths). The ISDN bandwidth is approximately 1/6th the capacity of current Digital Subscriber Line (DSL) services and 1/80th the download speed of current cable modem technology. However, the modem speed varies according to the number of simultaneous users within a given neighborhood.

Excellent videoconferencing technologies are produced by two firms (Tandberg, Inc. and Polycom, Inc.) that operate over ISDN, DSL and cable modems and they interface with document cameras, microscopes and other medical instrumentation. Not surprisingly, these companies control a sizeable portion of the telemedicine market because of the high quality of their products and user familiarity with the technology. The majority of telemedicine research has been conducted using either Tandberg or Polycom technologies. The National Library of Medicine also maintains a strong interest in telemedicine (see <http://www.nlm.nih.gov/research/telemunit.html>) and has a research program to evaluate the effectiveness of this modality at the Lister Hill National Center for Biomedical Communications.

Recently the availability of cheap public broadband service, more powerful computers, and inexpensive digital cameras has led to an explosion in free innovative communications tools that address the public's desire to do video conferencing on a budget. Skype is one current example, while Microsoft's Netmeeting (Microsoft, 2008b) was one of the earliest free tools widely available to the public. The latter product worked well for point-to-point video and audio conferencing and content sharing via a whiteboard and joint user interface. However, its ability to host multiple participants was limited to sites having a videoconferencing master control unit, which could be cost prohibitive. Netmeeting evolved into ConferenceXP (Microsoft, 2008a), a more reliable product capable of Digital TV-quality transmissions that can make use of experimental multicast IP technology. This can enable dozens of individuals to interact simultaneously (such as when multiple physicians consult with a single patient across large distances) without needing a master control unit. Unfortunately, this multicast technology is not yet available to the general public on commercial high speed networks such as Bright House's Road-Runner & DSL, or Verizon's FIOS. However, Multicast is accessible through experimental networks such as the Florida LambdaRail and nationally on Internet2's Abilene system. This means that major US universities (including all SUS institutions in Florida) may use experimental multicast video technologies to enhance medical care to their residents. The same is true for affiliates which connect via their regional optical networks. A prime instance of where multicast technologies might be beneficial to Florida is through simultaneous physician consultations provided to the "Big Bend Regional Healthcare Information Organization." As described previously, this federally funded endeavor connects healthcare centers throughout rural Florida.

While ConferenceXP can be customized to various settings (both with and without multicast capabilities), simpler videoconferencing tools exist for the less technically savvy who seek to interact with their physician from home using a PC, an inexpensive camera, and a high speed Internet connection. Skype (see <http://www.skype.com>), provides IP based point-to-point (but not multiparty) videoconferencing over international boundaries for free, although image quality can vary depending on available bandwidth and network congestion. Skype also furnishes simultaneous multiparty audio conferencing between several individuals without an expensive master control unit. Skype, like ConferenceXP, provides a shared whiteboard and shared file access for persons seeking to discuss documents

in realtime with their physician. Meanwhile, similar functions are performed by MSN.com's "MSN Messenger" and Yahoo's "Messenger" product. More than a dozen other low or no cost videoconferencing tools are presently available to seniors with high speed Internet access and an inexpensive computer camera. Like all third-party communications tools, users must be aware of the product's security characteristics, and how well it protects their health information against the risks of unauthorized disclosure. Once these issues are addressed, potential benefits include improved physician oversight of the recovery process in the home environment (even at a distance). For instance, the physician's ability to daily examine tissue regeneration at a wound site may translate to a better treatment outcome for homebound individuals.

Telemedicine applications may improve healthcare for the elderly if health professionals can observe the elder's physical condition through a video presence in the home. IBM Researchers (Husemann, Narayanaswami, & Nidd, 2004), describe a "Mobile Health Toolkit" that integrates cellular telephones having Bluetooth or 802.11 capabilities with a variety wireless medical devices (e.g. blood pressure cuffs, pill reminders, digital blood glucose monitors, activity monitors, respirometers, and needle injection monitors). The Toolkit establishes a wireless connection between the cellular telephone and any or all of the medical devices within approximately 10 meters. Each time a device was used, the time, date, and parameters measured would be relayed by phone to the patient's medical records at a remote server. Any failure to adhere to the medical regimen would be detected by a correlation engine running on the cellular phone. Poor compliance with these regimens in a home care environment was cited as a primary motive for developing this technology. Investigators also noted that "55% of all long term patients do not take their medication at all or at least 14 hours too late, resulting in a cost of at least USD 100 billion a year to the US tax payer --- and accounting for about 12% of the UK hospital admissions" (Ibid, p.48).

In home settings, telemedicine has also been demonstrated to improve mental health outcomes. Heeter and colleagues (Heeter, Gregg, Climo, Biocca, & Dekker, 2003) undertook three case studies of elders whose attendance at senior centers was curtailed due to illness. Each senior had bidirectional video and audio installed in their homes to allow them to continue to interact in realtime with friends at the centers. Heeter's subjects reported a diminished isolation and feelings of depression, though lighting problems at the senior centers occasionally made viewing and engaging in group activities difficult for the homebound seniors.

Communications technology has also been used by caregivers concerned about the ability of medical institutions to provide adequate care. By taking surreptitious photographs with camera-equipped cellular telephones, they can depict a facility's shortcomings in no uncertain terms. Although not strictly telemedicine, this further illustrates the value of cellular telephones in improving the quality of healthcare for the elderly. Meanwhile, studies have examined how communication technology can facilitate information sharing and support group activities among and between the professional and non-professional caregivers of elderly persons (Smyth & Kwon, 2004, Meier, 2000).

One of the most daunting specters for the elderly is dementia. Few disorders tear at the fabric of the family than the loss of a loved one's wisdom, intellect and humor. Progressive memory loss, agitation and confusion are hallmark characteristics for the four million persons (Hebert, Scherr, Bienias, Bennett, & Evans, 2003) who suffer with dementia. Pharmaceuticals have shown some promise in slowing its progress, but only if the affected person remembers to take the medication. Networked microprocessor devices like the "Health Buddy" link service providers directly to elders at home (telemedicine), and are proven to aid them in complying with medication regimens. A recent study by the Rand Corporation (Bigelow et al., 2008) evaluated the Health Buddy on a sample of 139 persons with congestive heart failure living at home. Participants responded electronically to frequent health management queries delivered via the device over monitoring periods of up to 4 months. The investigators found that participant compliance matched those of telephone-delivered queries. Furthermore, 90% of participants indicated they were satisfied with the technology; 70% felt no improvements to the technology were needed; and 70% said they would continue using the technology if given the opportunity. Other computerized devices that can retain several medication schedules are also commercially available.

Michael Ackerman and colleagues (Ackerman, 2004) (Ackerman et al., 2002) and (Field, 1996) have discussed the case for and against telemedicine from multiple perspectives. Their studies considered the growing range of technological options, the lack of compatibility between myriad telemedicine systems, and the hindering effects of reimbursement policies and licensure issues on the adoption of this technology by providers. Although telemedicine offerings continue to expand, the question of its economic viability as an alternative to traditional care is clearly awaiting a conclusive answer (Krupinski et al., 2006).

Ambient Computing, Smart Homes and Robotics

Ambient or pervasive computing argues that computing services or "machine intelligence" should eventually become ubiquitous. This school of thought contends that it will fade into the background at that point and thereby become "invisible" to the user (Aarts & Marzano, 2003). This viewpoint is being driven by the increasing miniaturization of computing hardware and the developing nanotechnology in materials science that allow these capabilities to be embedded in everyday items such as clothing and appliances. An IEEE engineering journal is expressly dedicated to the topic of ambient computing (i.e. "Pervasive Computing") and how its computing technologies are finding their way into everyday items. These include devices that can identify an individual and record their functional preferences (i.e. how you like your bread toasted). In the preceding section, an automated vacuum cleaner was provided as an example of how computing technologies could be embedded into everyday consumer goods.

As more people reach retirement age in the next 20 years, many of them will be at home with few institutional resources available for their care (Holahan, Wiener, & Lutzky, 2002). Normal declines in physical strength, sensory acuity, and working memory among the elderly (Hawthorn, 2000) are complicated by

chronic illnesses and other conditions. In addition to the uses that have been discussed, communication technology can compensate for cognitive and physical limitations in older persons and their (sometimes elderly) caregivers. However, this technology (as found in hearing aids, visual aids, text to speech processors, speech to text processors, electronic memory aids, and telephones) needs to be augmented through the corresponding evolution of services, products, and environments (e.g. telemedicine, robots, and smart houses).

Personal service robots

Industrial robot sales (the most numerous type) totaled \$1.4 billion worldwide in 2000 (Tanie, 2004). While this figure has consistently grown in recent years, run notes that "...personal service robots possess the highest expected growth rate. According to optimistic estimates (U.N. and I.F.R.R., 2002), the number of deployed personal service robots will grow from 176,500 in 2001 to 2,021,000 in 2005—a stunning 1,145% increase. Personal service robots assist or entertain people in domestic settings or in recreational activities. Examples include robotic vacuum cleaners, lawn mowers, receptionists, robot assistants to elderly and people with disabilities, wheelchairs, and toys" (run, 2004, p. 12).

Honda, Inc. has developed a humanoid robotic companion, Asimo, which performs basic chores and simple caregiving under voice, hand gesture, or network control. The bipedal device can walk at speeds up to 4 mph (see <http://world.honda.com/ASIMO/>) and is highly agile. Honda continues to extensively test the robot's capabilities, but its practicality to consumers remains uncertain as of now.

On another front, Montemerlo et al. (Montemerlo, Pineau, Roy, run, & Varma, 2002) tested a robotic Nursebot in an assisted living facility. While the Nursebot project is no longer in development, Montemerlo's patients reported being generally pleased with its functionality despite some problems with the speech recognition software which were later corrected. "Pearl" reminded patients of upcoming doctor visits, escorted them to the physician's office, and provided a stable platform to support slow moving patients as they ambulate.

The investigators stressed the importance of having the robot precisely estimate the pace of an accompanied walker in order to minimize the risk of injury. Meanwhile, Nursebot's speech recognition software also responded to patient requests and provided weather updates. Archived materials for Nursebot may be found at <http://www.cs.cmu.edu/~nursebot/>.

Another noteworthy advance was the mobile robotic information home appliance developed by Yoshimi and colleagues (Yoshimi et al., 2004). It was designed to come when spoken to by the user, operate other home appliances via infrared controller, and present e-mail or other communications through the home's network infrastructure. In practice, this device would attend to the elder's needs and function like a butler. The status of this project is unknown.

Jung et al. (Jung, Do, Kim, Suh, & Bien, 2005) were even more ambitious in constructing a complete smart house for the elderly and handicapped that employs wireless video and physiological monitoring of the resident. Other

features include an intelligent bed, robotic wheelchairs, and mechatronic lifting devices to assist in transferring infirm users. Preliminary evaluation of the home by a partially disabled 50-year old test subject was generally positive; though this environment was not tested with more aged persons.

While attention is primarily focused on complex solutions to the problem of communicating with persons with dementia, simpler technologies can also offer relief to caregivers. For instance, robotic dolls may play a role by stimulating communications in persons with dementia. They can also provide programmed cues and guidance to persons with memory disorders and act as a kind of electronic guide dog. Sony's newest version of AIBO (Sony, 2008) includes touch sensors, cameras, wireless networking and artificial intelligence that learn its environment and cause the robot's "personality" to change over time. AIBO can also stimulate personal response through six unique "emotions" (happiness, sadness, fear, dislike, surprise, and anger). Its onboard sensors and data recording capability may allow easier longitudinal behavioral data gathering in home and community settings where obtaining information on the progression of dementing disorders may prove difficult or unreliable. Tamura et al. (Tamura et al., 2001) demonstrated that simple baby dolls and toy animals can reduce agitation and increase social interactions among persons with moderate to severe dementia. The same group later found that animating the dolls produced significant increases in verbal interaction by demented persons (Tamura et al., 2004). These investigators presented an AIBO robotic dog dressed in baby clothes or an inexpensive electronic toy dog to 13 severely demented men and women. Patients increased communication with both toys, but were more likely to communicate with the inexpensive electronic toy dog. They referred to the dressed AIBO dog as either a dog or baby, and the investigators concluded that the robot's ambiguous identity may have made patients less likely to communicate because they were unsure which behaviors were appropriate. In contrast, the simple electronic toy dog reliably elicited behaviors characteristic of pet owners.

Wada et al. (Wada, Shibata, Saito, & Tanie, 2002) presented a robotic harp seal replica to 26 residents of a nursing facility over a period of 5 weeks. Approximately 38% of the residents had some level of dementia, and the investigators reported statistically reliable improvements in affect for weeks 2-5 among the residents using the Profile of Mood States questionnaire. They also found that persons with prior histories of breeding animals were more likely to benefit from exposure to the robot. Unfortunately, a placebo condition was not included to evaluate the effect of additional attention paid to the residents. A subsequent study by Saito et al. (Saito, Shibata, Wada, & Tanie, 2003) compared urinary stress hormones in nursing home patients who either interacted with the seal robot or a less sophisticated version that only had only a minimum set of programmed stereotyped behaviors. Their analysis showed that patients who interacted with the more lifelike robot had reduced stress compared to those who only encountered the simpler version.

Takanori (Takanori, 2004) has eloquently described the psychologically enriching value of service robots that interact with people: "Human interactive

robots for psychological enrichment are a type of service robot that provides a service by interacting with humans while stimulating their minds and we, therefore, tend to assign high subjective values to them. It is not necessary for these robots to be exclusive, but they should be as affordable as other new luxury products. In addition, accuracy or speed is not always of prime importance. Their function or purpose is not simply entertainment, but also to render assistance, to guide, to provide therapy, to educate, to enable communication, and so on. The market for human interactive robots designed for psychological enrichment is expected to grow rapidly and to become more widespread” (Ibid, p. 1751).

Conclusions

Hopefully, this report has succeeded in describing how a multilevel blending of digital communications from machine and human sources is now taking place, and that it may eventually be impossible to distinguish one source from the other. For example, many companies now use electronic telephone agents to preprocess billing information and make flight reservations. These systems are often lifelike, and some people prefer their soothing voices and functional efficiency to human interaction.

We are poised at the beginning of an era when most manufactured objects will have some form of communication capabilities. These may be manifested in embedded wireless networks, advanced nanotechnologies, or perhaps a machine that will entertain, serve, guide and possibly maintain and rehabilitate us through human mimicry when our biology begins to fail. These pervasive devices are present around us and perhaps even within us (consider present day wireless accessible heart pacemakers). They will form the “ubiquitous computing” environment described by Dishman, Matthews and Dunbar-Jacob (Dishman, Matthews, & Dunbar-Jacob, 2004). Dishman et al. envision environments that will enfold us as we mature. Their flexibility can accommodate changes at times, places and durations of one’s choosing. As a result, they can compensate for declining sensory acuity, cognitive or physical capacity. Communication technology that links human to human and human to machine will coordinate these customized environments. Their interfaces may range from simple telephone IVR systems to computer generated avatars, web interfaces, or possibly even robotic “pets” who will serve as wireless interfaces to larger communication networks. Perhaps the nanomachines in the objects themselves will soon be able to process commands and respond accordingly.

For healthcare policymakers, the near future will continue to witness an explosion in new robotic technologies, intelligent home healthcare systems, and significant advances in genetic research. This may eventually permit customized medications based on a specific individual’s genetics, though the precise nature of these advances remains unknown. It is clear that the trend towards enhanced access to medical records via networked machines (including wireless devices) will continue, especially as efforts by the federal Agency for Healthcare Research and Quality to perfect electronic medical records begin to bear fruit. The networked electronic medical record will of necessity play an instrumental role, as any automated healthcare system serving and monitoring care recipients will depend

on networked electronic medical records to function effectively. Its central role will ensure that the security of patient information remains an overarching priority to both administrators and care recipients.

Improvements in information security will therefore be required to sustain consumer confidence in these new technologies and emerging models of care. As a result, researchers and product developers must incorporate these improvements as their products evolve to meet the needs of tomorrow's Floridians.

Finally, it is clear that many caregivers of elderly Floridians are technology-literate. However, few may be aware of what technologies are available to them now (or on the drawing board) to assist them in caring for their aging parent or grandparent. Not everyone may be able to afford a robot caretaker, but most own cellular telephones. Simple technologies such as the GPS locator service option offered by Sprint, Inc. can be used to help find an elder who regularly carries a phone and who may have become confused and lost at the local shopping mall. It would be a good first step in making the general public aware of the presence of these options and their strategic benefits. One possible method of achieving this goal would be to publish a small brochure for caregivers that describe affordable technologies and how they can be applied productively. This could reduce some of the psychological stress that people who care for dementia sufferers face on a daily basis, thus possibly delaying the early placement of dementia sufferers in a nursing home.

With so much attention being paid to developing effective Gerontechnologies, there is plenty of room for optimism as long as the human element is sufficiently accounted for.

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