Creation of a Smart Apartment: An Evaluation e-Residence for All Abilities

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ABSTRACT

Individuals with disabilities frequently look to remain or become more independent in their homes. Accelerated development of home automation technology has made home control increasingly powerful and affordable for all consumers. The Smart Apartment at Helen Hayes Hospital was designed and created to give consumers exposure, experience, and education about the increased independence that a blend of current assistive technology and home automation technology can provide. Smart Apartment users can control 30 electronic devices; from the front door and intercom to the fan and blinds. These devices can be operated with all access methods including touch input, computer mouse, voice recognition, head/eye tracking, switch scanning, wheelchair input, and even brain wave signals. The Smart Apartment project is an example of a more inclusive unified approach to consumer-centered EADL and related equipment. The Smart Apartment is now an active demonstration, education and clinical evaluation center.

BACKGROUND

Consumers with disabilities improved their quality of life through control of these basic four devices; lights, TV, phone and bed . (Little, 2010) By the 1980s people requiring alternate access methods mostly relied on emerging dedicated environmental control units (ECUs). These dedicated niche products were produced in small quantities and infrequently updated. They were rather cost prohibitive for most consumers, and end-users lacked any local installation and technical support. Consumers had mixed experiences with ECUs, some were extremely satisfied but there was also significant abandonment of the technology. (Aiello et al., 2011), (Rigby, Joos, Cooper, Jutai, & Steggles, 2005)

Home automation systems (HASs) were likewise often dedicated specialty systems integrated by wealthy owners into their new homes. HASs were not commonly in use by people with disabilities because of their prohibitive cost and typically narrow accessibility options.

THE OLD MODEL: A 2-TIER APPROACH

Rehabilitation hospitals train patients prior to their discharge on home and food management skills. Trial activities are in categories such as cooking, laundry, making beds, bathroom transfers and other skills needed for a patient to safely return home after illness or injury. Until 2012 at Helen Hayes Hospital was no different. These transition activities, performed in a standard apartment, were incorporated into a patient's occupational and physical therapy regimens and were often target milestones for inpatients. These activities require a significant degree of independent mobility, balance, and trunk stability, at least fair reach and grasp, and functional vision and cognition.

The transition apartment at Helen Hayes had some samples of design adaptations that included built-up doorknobs, long lever cabinet and faucet handles, and wheelchair-height countertops. Patients were educated about more extensive design modifications and referred to vendors for more information. Patients with more severe disability (e.g. those who were unable to flip a light switch, use a standard remote control, or dial a phone) had limited potential for mechanical access to home appliances and activities and were often referred to the Center for Rehabilitation Technology (CRT).

Since the 1980s, patients who could benefit from electronic access received ECU evaluations in a separate CRT location. Patients were evaluated for access to a television and a small X10 circuit via various basic ECUs. Since the ECUs were targeted for specific home use each with idiosyncratic circuitry and appliances, it was difficult to evaluate for them in the clinical setting. (Little, 2010)

Many clients had home adaptation and environmental control equipment needs that exceeded the hospital's ability, therapist's experience, and the scope of available technology. Recommendations and planning for the creation of an accessible environment were left for the patient and their family to discuss mainly with equipment vendors and building contractors. Third party funding for home ECUs was scant. (Stickel, Ryan, Rigby, & Jutai 2002)

THE SMART APARTMENT MODEL: A UNIFIED APPROACH

The Smart Apartment was designed to have the flexibility for evaluation of individuals of *all* levels of ability who wish to increase independence across *any* activities of daily living. The Smart Apartment model puts physical access and electronic access on a single continuum. Washing dishes and changing TV channels, bathtub transfers and control of the bed position are all parts of one inclusive group of ADL skills. All patients are now considered eligible for exploration and training of equipment and techniques that move a patient towards increased independence at home.

The new Smart Apartment still provides a realistic environment, but one that demonstrates the many possible layers of adaptation. The apartment was designed to show simple mechanical adaptations up to the highest technology, including an apartment-wide voice recognition system with built-in wall microphones. In collaboration with the Wadsworth Center in Albany, NY, a Brain Computer Interface (BCI) application was also designed allowing control of all automated features by even some patients with locked-in syndromes.

Specialists involved in the design of the Smart Apartment were architects, electronics experts, therapists, clinical engineers, builders, and hospital administrators. We forged new and continuing relationships with knowledgeable electrical and security contractors as well as kitchen and bath remodelers. Patients provided input regarding which key household components required "e-Smart" technology.

A basic floorplan was designed that would allow demonstration of modifications per ADA requirements, while intentionally preserving areas that were not wheelchair accessible. Most patients will return to their homes 'as it was' or with only minor modifications. Significant remodeling is often not feasible, or they are not ready for major changes at home.

New Trends and Technologies

Beginning around the turn of the 21st century, new and maturing technologies began to amplify the power and scope of both ECUs and HASs. Evolving technology such as Bluetooth input and output peripherals, plug-n-play USB interfaces for specialized input (e.g. headmouse, and more recently, eyegaze), USB infrared and powerline emitters, powerful voice recognition applications, broad and inexpensive learning infrared technology, and faster processors (on laptops and wheelchairs) revolutionized the field of assistive technology.

According to Strategy Analytics, (reported in businesswire.com on 4/4/12), 61% of U.S. homes had Wi-Fi connectivity in 2011. The explosion of tablets and smart cell phones, and their innumerable apps have interlaced nicely with widely available Wi-Fi and cellular Internet access. More recently, usage of the wireless signal stream of residential LANs has been harnessed for data transmission to and from household devices. There are 382 matches for "iPad Home Automation" in the Apple App Store that will control locks, cameras, intercoms, outlets, music, thermostats, light sockets and bulbs, environmental sensors and more. New powerline transmission systems such as Insteon and UPB have eclipsed X-10, the former industry standard. Z-Wave and Zigbee are recent radio frequency transmission protocols.

Paralleling this burgeoning growth, over the last 15 years, clinicians interested in assistive technology have attained a standardized credential of Assistive Technology Professional (ATP). The terminology, "ECU", has largely been retired, and environmental control equipment was relabeled with more the consumer-centric "EADL" (Electronic Activities of Daily Living). Overall, newer technologies have broadened the options for all consumers including those with disabilities.

Although most individuals needing Assistive Technology solutions for EADL are those with pervasive or progressive disabilities, such as spinal cord injury or ALS, also individuals with milder limitations such as joint replacements and hemiparesis can benefit from some simple modifications. Many clients are under the mistaken impression that home automation must be expensive and complex.

The Smart Apartment technology builds on the nearly ubiquitous new access methods of touchscreen and voice recognition that are now so common on laptops, tablets and cellphones. Mainstream automation technologies, systems can be assembled from existing consumer electronics rather than building an entire systems *"from scratch"*.

SMART APARTMENT TECHNOLOGY SELECTION

Technology for automation was chosen to be as universal as possible in order to be a model for incremental and budget-conscious modifications. In the Smart Apartment the primary wireless transmission methods that tie any user's access to all electronic devices are Infrared and Wi-Fi signals. Infrared remote technology is not a new technology, but it is inexpensive and its signals are easily replicable. Moreover, consumers with disabilities who are power wheelchair and/or speech generating device users are often already equipped with universal learning remotes within their electronic equipment. Universal learning remotes are thus among the most powerful access devices in our Smart Apartment and a list of their configurations are in table 1.

Table 1. Universal IR Remote Configurations

Universal IR Remote	Access Method
Relax from Ablenet and Angel ECU.	Single/dual switch.
Voice IR from Broadened Horizons.	Voice

Sicare/Pilot from Ablenet.	Voice or single/dual switch
L5 Remote for iPad and iPhone with accompanying App.	Touch
Wheelchair control IR transmitter from Quantum, Permobil and Invacare.	All wheelchair access methods including sip-n-puff switches and head arrays.
Speech Generating Devices with built-in IR from manufacturers such as Dynavox, Tobii/ATi, and Prentke-Romich.	All augmentative communication access methods including scanning and eyetracking.
USB Universal Infrared Transmitter (UIRT) with controlling software.	All computer access methods including voice input, eyetracking and headmouse.

Universal Powerline Bus (UPB) was chosen to control lighting and outlets. Direct relay connections were used for the automatic door opener and the electric bed. Each item to be controlled was therefore selected only if they could be controlled by at least one of IR, UPB, or the direct relays methods. Items specially designed for individuals with disabilities, such as the motorized wardrobe and the automated toilet could be special-ordered with an IR remote. Devices that did not include infrared remote controls were fitted with aftermarket infrared sensors and provided with IR signals with a kit. Infrared transmission's weakest characteristic is its necessity for line-of-sight orientation. An apartment-wide infrared receiver and transmitter system greatly alleviated this problem. The different ways devices are controlled by infrared signals or the ways they were adapted for IR, are outlined in Table 2.

Table 2. Items of Control and Infrared Control Methods

Item of Control	How Infrared Control Signal was Established
Televisions, DVD Player, Air Conditioner, Motorized TV Mount, Ceiling Lift, Desk Telephone, Automated Toilet	Manufacturer-designed Infrared was provided.
Blinds, Computer Desk, Wardrobe Lift	Special-order Infrared could be provided.
Lights, Outlets, Thermostats	HAL module converted Infrared signals to Universal Powerline Bus (UPB) signal.
Door Opener, Custom Voelker Bed Control, Kitchen Computer Arm, Intercom	Infrared to relay converter kit to activate specific switches.
Ceiling Fan	Custom conversion of Radio Frequency remote to relays.

System Integration

Receipt and transmission, management and coordination of these IR and Wi-Fi signals were processed through equipment from Home Automation, Inc. (HAI) and Home Automated Living (HAL). The Omni Pro from HAI and the HAL Professional Server are the specific centralized control systems. These systems allow local intranet access, remote access via the Internet as well as through streamlined Apps for either iOS or Android platforms. HAL is notable for its speaker-independent voice recognition control method.

Evaluation

Ideally, anyone considering home renovation to improve access for someone with a physical limitation will visit the Helen Hayes Smart Apartment. Anyone with a disability will come for an assistive technology evaluation prior to undertaking any home modification.

Individuals who seek home automation evaluations at the Smart Apartment can be referred by anyone, but as outpatients they will need a physician's prescription for the Evaluation. Medical Insurance coverage is confirmed as it is the most common payer for these evaluations that can also be coded as OT, PT or Speech therapy evaluations.

The evaluation takes place in the Smart Apartment where, after a basic orientation tour a CRT therapist conducts a thorough needs assessment that helps to clarify a consumer's home automation priorities. The next step is for the evaluator to identify current and other viable access methods. The needs assessment highlights specific activities of daily living (ADLs) in which the consumer wants to increase independence and it points to specific equipment to trial and understand. The client is then set-up to trial the various devices in the Smart Apartment using one or more access methods. Choosing a particular access method does not determine specific equipment. The Smart Apartment has at least 7 different voice input system options, some of which can run on multiple platforms. Whenever possible and appropriate we try to build from or integrate existing technology such as a wheelchair controller's IR transmitter.

From the evaluation the CRT evaluator can determine and document the type of equipment and access that the client requires and give examples of sources of this equipment. Smart Apartment therapists can facilitate communication between the patient and the builders and equipment suppliers who will follow-up with them at home.

Every effort is made to explore all potential funding sources.

CHALLENGES AHEAD

A general lack of education about new environmental control technologies contributes to a community of disabled individuals that do not realize their potential to live a more independent life. Educating clients about home modification and automation, allows them to better select contractors who have a true understanding of adaptations needed particularly for those with severe disabilities.

The Smart Apartment's unified approach has exposed a divide in therapists' clinical expertise. Therapists who are knowledgeable about adaptive equipment for the bathroom need to become familiar with e-access options as well

Funding for modifications of the home environment is still difficult to find. The unified approach we have taken to

promote increased access across all ADLs and EADLs should influence public policy and medical insurers to expand the definitions of durable medical equipment to include coverage for equipment that increases independence at home.

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