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Chapter 13

Low Usage of Intelligent Technologies by the Aged: New Initiatives to Bridge the Digital Divide

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ABSTRACT

Engineers have developed many assistive technologies to aid mankind. However, one finds that the elderly and disabled do not adopt many of the current technologies in their daily lives. This form of the "digital divide" has manifested in very low usage levels of high technology devices within this population.

Human beings exist in two environments, internal and external. Internal environment relates to perceptions, self image, emotions and motivation levels. External environment is the physical body, and the world around them. There is a constant interchange between the inner and outer worlds with each having an effect on the other.

This chapter will address many of the issues that this topic raises and propose viable solutions. The aim is to bridge these two environments and connect them meaningfully through “sensitive” technologies designed to take into account the perceptions, mindsets and different learning mechanisms of users.

INTRODUCTION

The development of assistive technology (AT) has tried to focus primarily on helping the elderly cope with physical tasks, activities of daily living, accessing entertainment and using communication tools to exchange information. Hence the approach has so far been to enable interaction with the outside environment.

We find, however, the usage of such technologies among the aged have not shown the dramatic rise that may have been expected. The low technology objects in both rehabilitation and assistive technology have the highest usage. So it seems that this population is more comfortable with technology that has a high level of usability and affordability, even though the device may have a low level of intelligence.

Wikipedia defines the digital divide to be,

“The gap between people with effective access to digital and information technology and those with very limited or no access at all. It includes the imbalances in physical access to technology as well as the imbalances in resources and skills needed to effectively participate as a digital citizen.”

Access and Affordability

The socio-economic-developmental disparities within and across countries was considered to be a major impediment to easier access and higher usage of AT. Even if access was provided, the next question was whether the people would be able to afford it. The digital divide does not stop at mere access to online information and information technology, it is also about being able to afford access. Over 70% of blind and low vision citizens in the United States are unemployed. People with other severe disabilities have similar employment statistics. Assistive technology software costs as much over USD 1000 for a screen reader that enables blind people to use their computers, which means that access to computing is out of reach for the majority of Americans with disabilities (“Findings About the Awareness and Use” n.d.). For people with severe motor disabilities, few systems are suitable for individual ownership. More so if we consider people from developing countries.

While several organizations and countries are working towards closing this gap, there is another emerging “divide” between the elderly users and “intelligent” assistive technology. Affordability and availability alone may not necessarily translate into long term usage of assistive technologies.

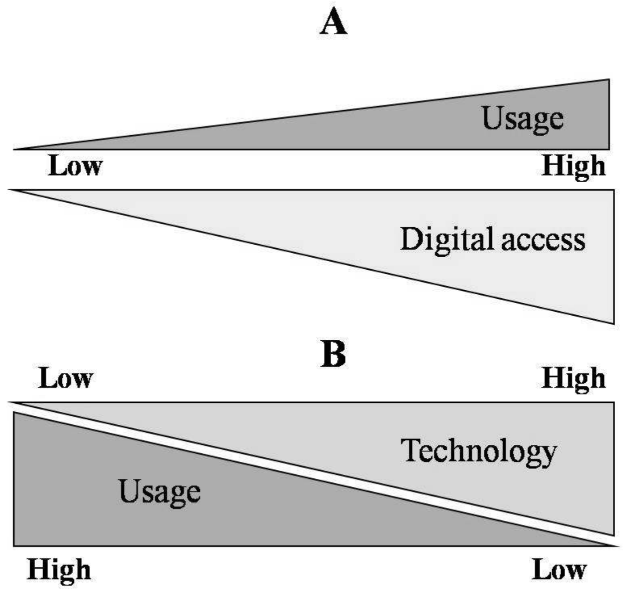

Figure 1. Two aspects of the digital divide. A) High access-high usage B) High technology-low usage

Figure 1 shows that usage is seen to rise in smaller proportion as compared to access. The other divide we wish to point out is shown in (B). Low intelligent products have the highest usage. As technology gets more complex, usage plummets.

Sensitivity to the Internal Environment

Simple mechanistic models for physiological recovery and aid stop working so well when we talk functional activities or movements which have higher levels of complexity. Then there is the question of what the person wants to achieve with the assistive or rehabilitation device. For example, moving fingers may be just aimless repetitive movement or they can produce an inner expression of the soul like music or a painting.

Several bodies of research from medicine, neuroscience and physiology have shown that it is possible to recover or maintain many inherent faculties in the aged, which may have deteriorated from disuse or damage. These include memory, mobility, motor function, audio sensitivity, cognition and so on (Clark, D.O., & Stump, D.E., 1998; Hofgren, C., Bjorkdahl, A., Esbjornsson, E., & Stibrant-Sunnerhagen, K., 2007; Williams, J., Ramaswamy, & D., Oulhaji, A., 2006). The self-determination theory (Deci, E.L., Eghrari, H., Patrick, B.C., & Leone. D.R., 1994) states that humans who are naturally motivated tend to incorporate an internal regulation strategy for all important activities. It has been also proven through several studies that attention, motivation and repetitive task practice are essential factors in the reorganization of the brain (Bach-y-Rita, P., 2001; Berthoz, A., 1996; Robertson, I.H., & Murre, J.M.J., 1999) which can take place well into old age.

It seems that the major factors affecting this recovery or maintenance relate to the high level of engagement of the individual with the task at hand. Studies in psychology and accelerated learning highlight that such high levels of engagement occur when there is an "emotional connect" for the individual to the task and when all sensory pathways like visual, auditory and kinesthetic pathways are brought into play. This can happen when there is an active, collaborative environment (Loureiro, R.C.V., Johnson, M.J., Harwin, W.S., 2006).

Both rehabilitation science and AT have given little attention to the mind-thought process-emotion combine of a user. Traditional and alternative healing and recovery methods like yoga, Chinese traditional medicine, hypnotherapy, and martial arts confirm the dramatic benefits of increases in inner awareness, sensitivity, self confidence and modification in perceptions of self and society. These factors have been shown to directly affect not only progressive degeneration due to ageing but also sudden acute events like stroke (Bastille, J.V. & Gill-Body, K.M., 2004; Kolasinski, S.L., Garfinkel, M., Tsai, A.G., Matz, W., Van Dyke, a., & Schumacher, H.R., 2005; Song, R., Lee, E., Lam, P., Bae, S.C., 2003). Certain developments in modalities like bio-feedback and collaborative therapy have shown very promising results (Hayashi, K., 2002; Martinez, P., Bakardjian, H., & Cichocki, A., 2007; Wallace, B.E., Wagner, A.K., Wagner, E.P., McDeavitt, J.T., 2001).

BACKGROUND

Current theories of motor function adopt two completely opposite points of view. One states that the body follows the movement form using constraints for control, whereas the other says that the form follows from the functioning of the body (Berthoz, A., 1997). Bernstein emphasized that the basic problem of natural movement is one of co-ordination."The co-ordination of a movement is the process of mastering redundant degrees of freedom of the moving organ, thus making it a controllable system" (Bernstein, N.A., 1957). Between skeletal and muscular geometry, nature has found a skilful and highly sophisticated yet simple way of controlling the redundant degrees of freedom in countless day-to-day actions (Berthoz, A., 1996).

The Journal of Neuroengineering and Rehabilitation, 2004-2007, lists interesting bodies of work such as biologically inspired neural networks controllers, computer assisted motivation systems, markerless motion capture of human movements, wireless body area network of intelligent motion sensors. However, we are still in an age where try as we might, computers and robots can at best act as aids. The synthesis of technology and clinical practice has been mandated in this century by the dramatically increasing numbers of the aged and disabled. This coming together demands a re-evaluation of certain design criteria, so that user motivation, cost and versatility are adequately addressed.

The Traditional Approach to AT

The "raison d'etre" of AT is the improvement of quality of life (QoL). Technologists have believed so far that a better QoL means an easier way of executing activities of daily living (ADLs) and certain other tasks related to personal physical comfort, transport, communication and health monitoring.

Traditionally, AT started off as devices to help accomplish simple tasks. Hence early devices like walking aids, spectacles, etc. were strictly functional. A simple device like a remote was created to establish control over a reasonably intelligent device like a television set. While the basic function was to turn on/off, surf channels, and adjust volume, several personalization features were also incorporated as technology progressed. Currently, the remote controls a wide array of features, most of which are not regularly accessed by the elderly. They still use the remote for the basic functions. One can say the same for mobile phones. However, some features such as text messaging and sharing photographs have succeeded in making mobile phones a more widely used tool than was achieved by merely telephone features.

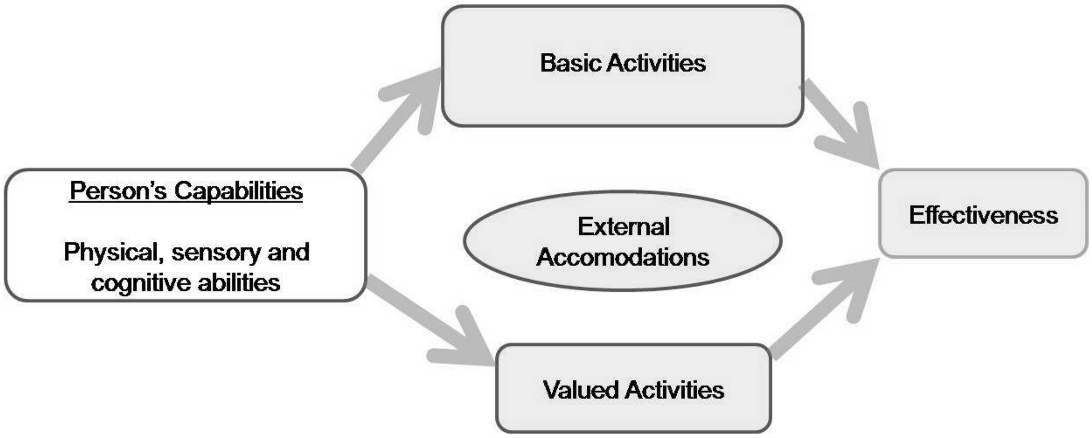

Figure 2. Traditional approach to AT design

Seeing the encouraging usage of low technology devices which used the concepts of a single switch, it was assumed that as AT products became smarter and made life easier, they would enjoy larger usage. However, the usage is still abysmally low especially in view of the fact that populations of elderly as well as disabled persons have increased steadily.

Figure 2 illustrates the traditional approach to AT design over the past few decades (Freedman, V.A., Agree, E.M., Cornman, J.C., 2005). The starting point in drawing up the specifications is an assessment of the persons functional capabilities at the physical, sensory and cognitive levels. Next the activities that the device is meant to help with are identified. The types of accommodations are then established for the effective execution of these activities. Technological intervention may generally be used for the following:

1. Augmenting the person's capabilities: This is done by enabling better mobility, stability, positioning ability, force generation, control and so on.

2. Providing Accommodations: This is usually done by engineering the environment so that the task in question is easier to execute.

The early approach to focus on basic tasks has persisted, resulting indirectly in a larger emphasis on basic activities such as ADL/IADL, communication, mobility and accessing entertainment. Consequently Figure 1 shows the "Basic Activities" block much bigger than the "Valued Activities" block, to illustrate this.

As the pace of life increases, the need for independent living among the aged has been growing. As a person ages, he/she finds himself/herself trying harder to remain functional. The motor and cognitive impairment becomes the new reality. When this happens, the levels of accommodations need to change so as to compensate for this decrease in the person's capability. Some "intelligent" AT device succeed in adjusting the accommodation levels seamlessly, most others cannot.

This has an immediate impact on the self-image and the patient perceives himself/herself as a dependent and an increasing burden on family and society. This gives rise to new independence and relation needs (Goldberg, R., 1984; Maclean, N., & Pound, P., 2000). If hit by a sudden disability, individuals above 65 years of age may also lose interest in independent living and believe they will never improve (Lewis, C.B., 1984). On the other hand, every ageing person is keen to retain their vigour and vitality for as long as possible because independence is closely intertwined with human dignity.

People with motor impairments use their unique motor abilities to operate assistive technology devices so that it facilitates their work, recreation and daily living tasks. AT devices are at their most effective when users deploy their own unique motor abilities instead of trying to move in a manner that is considered “normal” (Bain B.K., & Leger D., 1996). People who are aware of their residual strengths adapt fastest and lead productive lives. Being essentially multi-tasking in nature, they are best served by a system which allows them some facility to do so.

Awareness and Usage : Lessons from the Computer Industry

Let us consider the scenario in the computer industry which has been one of the pioneers in the propagation of accessibility features and assistive technologies for its users.

Accessible technology enables individuals to adjust a computer to meet their visual, hearing, dexterity, cognitive, and speech needs. Although most accessible technology was originally intended and designed for individuals with severe difficulties/impairments, accessible technology is widely used by computer users of all abilities today. The technology includes accessibility options built into products (such as the option that changes font size and colors) and assistive technology products (specialty hardware and software products such as a screen reader or voice recognition product). Assistive technology products are specially designed hardware and software products that are chosen specifically to accommodate individuals with visual, dexterity, hearing, speech, and cognitive difficulties and impairments. Many individuals who need these products cannot effectively use a computer without their assistive technology product because of a difficulty or impairment.

In a study commissioned by Microsoft in 2004, it was found that the majority of computer users (54%) are aware of some form of accessible technology but few are using it (“Findings About the Awareness and Use” n.d.). Awareness is fairly uniform across all types of difficulties/impairments with the exception of cognitive difficulties/impairments for which awareness is slightly lower. Awareness is lower among computer users with severe hearing, speech, and cognitive difficulties/impairments compared to those with severe visual and dexterity difficulties/impairments.

Similar to awareness, assistive technology product usage is highest among products that are more widely used by the general population and lower among more specialty products designed for specific difficulties/impairments. Assistive technology products are not as commonly used as built-in accessibility options/utilities because assistive technology products require a separate purchase and installation.

This study also showed another interesting result. Individuals with and without difficulties/impairments are turning to accessibility options/utilities to improve their overall computing experience. Participants who use assistive technology were asked to report if their use of assistive technology was due to an ongoing health issue, a health issue they had recovered from, avoiding a health issue, or assisting someone in their household with an ongoing health issue. The majority, 65%, of assistive technology users did not report any of these health issues as reasons for using assistive technology products. The second most likely reason assistive technology users report using assistive technology products is to avoid a health issue.

When users of assistive technology products were asked if additional assistive technology products would enhance their computing experience, only 21% of computer users with severe difficulties/impairments and 17% of computer users with mild difficulties/impairments believe that additional assistive technology products could enhance their computing experience.

Small wonder then that usage percentages of assistive technology products were shown to range from 1-9%. Only 24% of computer users with severe difficulties/impairments currently use assistive technology products. A key component of encouraging the use of accessible technology is to make it easier to find and highlight the functionality and benefits rather than the impairments they seek to ameliorate.

NEW REALITIES FOR EMERGING NEEDS

Cultural Perceptions of Dependency and Dignity

The social structures of the West and the East differ in several ways. One of the most prevailing is the different priorities accorded to independence and interdependence. The West promotes independence of the individual while acknowledging some levels of interdependence. In the East, interdependence plays a big role in the traditions and social aspirations of people.

In many traditional societies, elders do not mind being physically and materially dependent if they are seen as contributing members of the family. They help the family in an advisory capacity as well as look after the value education of the grand children. This has to some extent off-set the demands on time for “double-income” parents. Hence their contribution is tangible and economically valuable since their needs are few. The youngsters and children of the family learn to be sensitive and caring in turn towards the elders. But when disease and disability manifest, the economic, social and emotional pressures on the family rises. If the elders are now not in a position to look after their own medical expenses, their sense of self-worth suffers and they consider themselves a burden. In many cases, the children prefer to start living on their own, pursuing a lifestyle which has no place for the elderly.

Increasingly, all over the world and across all cultures, we find the elders socializing regularly amongst themselves. You have clubs, societies, resorts, community programs, networking associations all tailored towards bringing the senior community closer to each other. While the need for independence is strong, social inclusion and engagement seems to bring a higher level of fulfillment. At least in countries in North America and Europe, we also find the elderly taking up some alternative employment after retirement, travelling together, learning new things.

The common thread that permeates societies all over the world is the search for dignity in old age, and it is closely intertwined with remaining not only independent but also "useful" and "contributing" members of the family or society.

The question that arises now is should we design AT devices to focus on merely independent living or to focus more on "dignified and useful living"? In the emerging scenario, the lower functionalities such as ADLs may be best left to low intelligence devices which are safe, cheap and easily adopted. The smart devices will make sense to the elderly only if it can enable a higher goal to living, else the cost and the time taken to understand the technology may not be worth it, especially with rapid changes in technology platforms. These higher goals logically seem to be greater social inclusion and a more useful role in society. Keeping in mind the direction of medical costs in the past decade, maybe even the opportunities of post retirement employment or income may become a key factor in attracting more usage. Activities related to these higher goals can be incorporated to the list of "Valued Activities" in Figure 1.

Yoga, Martial Arts and AT

The emerging research on brain plasticity has revolutionized the way in which we perceive the aged population.

Studies have proven that even mental imagery results in improvement of motor and cognition recovery after stroke (Pfurtschellar, G., & Neuper, C., 2001). Both yoga and martial arts use mental imagery and visualization to a great extent to enhance levels of co-ordination, balance, speed and power. Elite athletes all over the world have used bio-feedback and visualization to overcome subconscious mental blocks which hinder performance.

The techniques of mental imagery and visualization mentioned above utilize the visual-audio-kinetic (VAK) sensory feedback route, since all the physiological systems are healthy. This combination of physical effort with heightened awareness has benefited millions of young and old through thousands of years. Due to the deeper levels of awareness with oneself, and the resulting sense of psychological and emotional well-being, practitioners continue to stay involved with the practice although they enjoy good health.

The chanting of syllables and sounds, the rhythmic beats of gongs and drums have been used for centuries to bring practitioners to a meditative, attentive, alert state to facilitate the control and training of physical control over the sympathetic and parasympathetic nervous systems and the musculo-skeletal structure. This is essentially a form of not just brain entrainment but entrainment for all the rhythms of the human body such as circadian and breathing rhythms.

All such traditional systems of healthy living stress on two modes of practice, individual and collaborative. In solitary practice, one gets in touch with one's inner world more intimately while in collaborative practice, one establishes one's position with respect to the external environment and one's peers, seniors and juniors. Long time practitioners become adept at quickly adapting to changes in both environments, especially with advancing age. Many of us have met or read about such people living full, productive lives well into their late seventies and eighties, physically fit and mentally alert. Ms. Theresa Tsu, who set up Heart To Heart, Singapore, is a shining example. Already past a 100 years, she works tirelessly for the care of the old and disabled, practicing yoga everyday. Several studies have shown that even those who start after the onset of disabilities due to osteoarthritis or stroke, benefit from this system, gaining a new awareness and control over their daily activities (Bastille, J.V. & Gill-Body, K.M., 2004; Song, R., Lee, E., Lam, P., Bae, S.C., 2003).

The question then is can these time-tested principles be leveraged as a tool to improve inclusive, sensitive AT design? Chinese martial art teachings stress on the interdependence of Xin-Yi-Qi or thought-purpose-energy-action and its cyclic nature as shown in Figure 3.

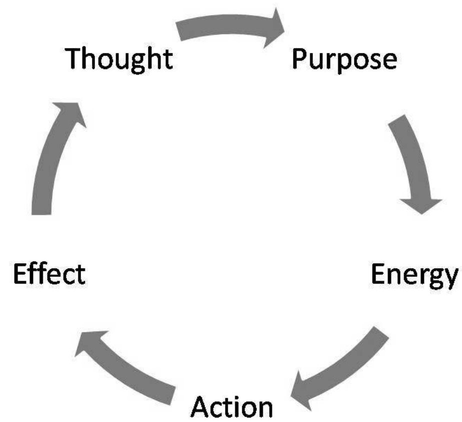

Figure 3. Movement in the user's inner world manifesting as action and effect in the outer world. This in turn again affects the thought process, hence feedback and acknowledgement of small successes are important.

Translating Theory into Practice

In the rapidly evolving communications industry, consortiums like IGADD (International Group against Digital Divide) are working towards bringing "Meaningful Broadband" to 50 million Indonesians by 2012. They have defined "Meaningful broadband" to be "usable, affordable and empowering" ("Ushering in the second digital revolution" n.d.).

What are the hurdles that prevent AT from being perceived as usable, affordable and empowering? One of the ways is to incorporate these 3 terms into our definition of "Effectiveness" in Figure 3.

Human beings do not use their bodies, minds and sensory faculties in isolation. The activity of going about life in a fulfilling manner involves the integration of these abilities. There is a need to highlight new initiatives being taken in various studies and experiments to develop technological platforms which involve multi-level interfaces. The use of the term multi-level denotes both the engagement of the user with his inner and outer worlds as well as the interaction with the AT device at multiple levels. This new approach focuses on usability, simplicity and engagement.

Such multi-level platforms will make it possible for the aged to re-connect with their own residual capabilities at the physical, sensory, cognitive and adaptive levels. At the same time, it will allow interaction with others through self expression and collaborative activity. Multi-level platforms can be adjusted as the person improves or deteriorates over a period of time.

This brings us back to the question of using technology to bridge the digital divide effectively by designing the system to bridge the external and internal environments of the user. Just like the external environment which he or she is able to see, perceive, adjust and control, a user can, by adopting a new approach, be given the same capabilities to deal with the inner environment.

Figure 4 illustrates the new aspects of the inner environment which is shaping the use of assistive technology today.

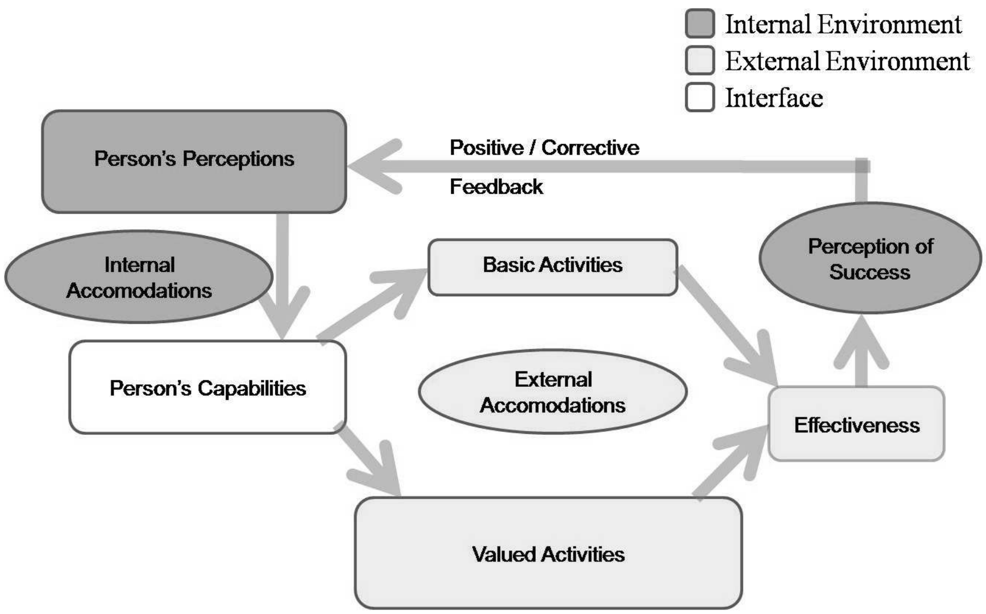

Figure 4. The user's capabilities forms the interface between the inner and outer worlds and reflects the quality of the integration of these two aspects. It allows for "inner accommodations".

Once again the relative sizes of the blocks illustrates the relative importance of the various aspects. In the new scheme, the person's perceptions and its understanding plays a large role in the design of the AT system. The perception may typically include,

- Self image,
- Benefits of doing given task,
- Perceived degree of difficulty,
- Perception of progress/ recovery/ success in task/activity,
- Role in society,
- Cost and utility of AT device

These issues would directly impact the person's capabilities, which now would have to include certain new parameters, such as

- Physical, cognitive, sensory abilities (as in Figure 1)
- Level of training on the technology platform
- Levels of motivation, confidence/ anxiety based on perceptions listed above

Hence the new approach acknowledges that the capabilities undergo changes at levels other than but closely related to physical, cognitive and sensory faculties. The "internal accommodations" mean the user's inner belief about his/her capabilities and the life decisions that lead to a change in mindset.

We have see in the previous sections that it is not necessary that people's choice of technologies is dictated by their levels and type of disability. What they are looking for is a "richer experience". This is borne out by the rise in use of mobile phones for messaging and sharing by the aged, which traditionally is technology averse. This mandates a closer look at what we, as designers, perceive as "Valued Activities". Rather than just work and leisure, it needs to incorporate

- Social engagement
- Self-expression, self growth
- Social contribution.

"Effectiveness" is similarly extended to include the ability to generate and receive appropriate, valuable feedback through the activities, in a multi-modal VAK format.

STRATEGIC APPROACH TO A RAPIDLY CHANGING SCENARIO

In its simplest form, an assist device like a walking stick provides support along with some form of tactile feedback about load distribution and imbalance. Anybody who uses crutches for the first time knows that it takes a couple of days to learn how to use them to walk, sit, get up and use a staircase. The care giver may give verbal instruction and physical assistance. But the most over-riding form of feedback is visual and kinaesthetic. Using these input signals, so to speak, one rapidly progresses towards being comfortable on crutches during recovery from lower limb injury. It is far easier an adjustment if a friend comes along for a walk, so that one can chat, have a drink or meet up with some more friends. An outing like this assures the recovering person of at least a couple of hours of practice with the assist device. Yet if anyone asks them how they occupied themselves, they will probably respond that they "went out with friends".

In this manner, a so-called low intelligence technology like a crutch becomes a 'sensitive" device, allowing the user to utilise his or her own residual intelligence and capability. It enables social inclusion, human-to-human interaction during use and is easily affordable. Of course, it does not look pretty. A modern powered wheelchair, on the other hand, looks very sophisticated and elegant but many elders would rather not use them since it affects their self-image.

Most high technology devices are restricted by high complexity, high cost, long learning curves, etc. This means that apart from coping with the physical disability, the person must now also cope with the technology. If the person is elderly and happens to be technology averse, one finds a rapid loss in motivation and an increase in frustration, unless he or she is able to see "incremental successes".

In the face of this reality, rather than a functional task-based approach, a strategic approach is now necessary so that the wonderful possibilities of assistive technology come closer to the people. In the past couple of decades this has gained urgency due to the exponentially increasing elderly and disabled population. The onset of disabilities at a younger age has compounded the problem. The changing scenario can be characterized by the following:

- High technology has not translated into high usage among the elderly.

- Issues related to equal access still persist. Better access has not translated into a proportional increase in usage.
- There has been a drastic increase in the numbers of aged and disabled who are therapist and care giver dependent
- Motivation, cost and versatility are the new concerns

New evidence in research points to important aspects which need to be incorporated into technology development. Some of these are

- Few users can cope with high technology, usually it is the younger and mildly affected
- Several hours of daily therapy can help recover function even in the aged, due to the phenomenon of brain plasticity
- Motivation and social inclusion is key to quality of life.

The strategic response, therefore, would be to include new parameters to the design checklist.

- User and Care Giver "sensitive" inclusive approach
- Motivation management
- Reduction of cost
- Use in collaborative scenarios

NEW DESIGN PARADIGMS

Newell (1995) had suggested that researchers should focus on the relationship between the functionality of users and the environment in which they may operate. This concept has been fully exploited by the "Jaipur foot", a prosthetic device which is tailored to the user and the environment in India. It is the world's cheapest (less than USD 50) and highest selling prosthetic leg, allowing millions of users to lead their rural lifestyle walking barefoot, squatting on the floor and even climbing trees. Usable by lower limb amputees of all age groups, it is aesthetic and made from recycled automobile tyres. Instead of being part of the medical insurance system, it is distributed through a non-profit organisation, Jaipur Foot Foundation, to all corners of the globe ("What is our special technology?" n.d.).

In devices of higher intelligence, if portability and functionality is required, the user interface is limited in its bandwidth of channels as in the case of mobile phones with alpha numeric input requirements. This limited bandwidth then becomes the limiting factor in the human-machine system (Angelo, J., 2000).

The Human Activity Assistive Technology Model (HAAT) encompasses four parts (Nielsen, J., (1993):

- The human-technology interface

- The processor
- The activity output
- The environmental interface

This model acknowledges that the activity enabled by AT takes place not only in the physical context but also in the social and cultural context. User centred design (Helander, M., Landauer, T.K., & Prabhu, P., 1997; Nielsen, J., 1993) developers used to focus on the interface of the user and his external environment. The user sensitive design is now exploring how best to present information to the disabled user in various modalities, such as audio-visual-kinesthetic cues and bio-feedback.

VAK and Bio-signal Feedback

There is a lot of research being done in the areas of learning and social interaction for both normal, developing children as well as children with special needs. Therapy with children struggling with, say, Autism and an aged person patient trying to come to terms with the aftermath of stroke or other disability may have common elements as listed below:

1. In both children as well as adults who have recently suffered cerebral trauma, the brain is in an elevated level of neuroplasticity for a particular, limited time-window.

2. Both groups suffer from low self-image and low social interaction.

3. Both groups have very short attention spans and inability to hold focus (especially if the stroke patients have some aphasia)

4. Both groups may have related issues with motor function and sensory feedback.

5. Motivation to change in both groups is largely low.

The emerging concept of "Collaborative therapy" where two persons collaborate with each other or with their care givers or friends or with growing children shows great promise, in that it re-introduces the patient (who has felt isolated so far as an invalid) into the social milieu. Using universal design principles in the design of such " Collaborative Play Devices" will enable the patient to interact with whosoever he or she pleases, be it an infant or an elderly friend, able bodied or physically/mentally challenged. Studies also show that collaboration between users have a positive effect on prolonged usage. This prolonged engagement in the activity is the first step for brain plasticity to occur and restore some of the impaired functions in part or full (Meinzer, M., Elbert, T., Wienbruch, C., Djundja, D., Barthel, G., & Rockstroh, B., 2004).

So far, the case of interactive play has been seriously addressed only by Virtual Reality, where a patient is able to respond to / elicit response from a virtual object or person. But the experience of interacting with a real person is far richer and more stimulating to the various senses. It also brings into play more hand movements and upper extremity manipulations rather than being restricted to a mouse or a joy stick, and a computer screen.

One sees great promise for the aged in concepts being developed for children with disabilities. The "Siftables" is a new interface which involves VAK cues and feedback at every stage, in the process of solving problems by understanding spatial relationships. These are building blocks which are intelligent and able to guide the user intuitively (Merrill, D., Kalanithi, J., Maes, P., 2007). While it exercises no control over what the user does, it provides both visual and audio cues and feedback for creating various combinations, whether it is used to create an image or create music. Since the blocks engage the motor function, we see a high level of "engagement" of the user with his internal and external environment. Simple devices like a metronome which provides auditory or tactile feedback enables both the elderly and the young in different ways.

Progress in the field of acquiring, processing and using bio-feedback in a simple, portable format is gaining momentum all over the world. EEG systems like Emotiv (http://www.emotiv.com) and new communication protocols (Paulson, L.D., 2008) are demonstrating that one need no longer be hampered by high cost, high footprint and long set-up times. While Emotiv is planning to use brain signals for gaming, others are developing special data acquisition electrodes and wireless systems. This has opened up the possibility for the aged to "see" much more about what is happening in the internal world, and use it to carry out "internal accommodations" (See Figure 4).

According to Frank H. Duffy, MD, Associate Editor for Neurology, Clinical EEG Journal, 2000,

"The literature, which lacks any negative study of substance, suggests that EEG Biofeedback Therapy should play a major therapeutic role in many difficult areas. In my opinion, if any medication had demonstrated such a wide spectrum of efficacy it would be universally accepted and widely used."

Age brings with it several progressive disabilities which may become debilitating after a point. Neurofeedback can identify the onset of many states such as high stress, low attention, and hemispheric asymmetry and allow a person to train his brain waves to reclaim the diminishing faculties. Similarly SEMG feedback has been shown to be very useful in the retraining of the kinetic chain and functional movements after surgery or injury in old age, helping the person to recover a substantial percentage of motor capability.

Neurofeedback is a direct method of intensive attention training. During the training the brain's activity is controlled consciously and unconsciously by the direction of attention. As the client becomes aware of how he/she can control and maintain the feedback signal by staying calm, alert, present and generating the right brain patterns, he/she can choose to stay in this state for up to 40 minutes. The brain gradually tunes in on the feedback signal intuitively. These new skills are internalised during the training and automatically transferred to the person's daily activities.

On the physiological level the intensive training of attention seems to stimulate and promote neurological coherence, growth and maturation processes in the brain. This occurs during training when the neurons are stimulated to create new synaptic connections improving brain functions in the concerned areas. There is evidence that brain wave training increase blood flow to the brain. Brain scientists found a negative correlation between Delta/Theta (lower frequency brain waves) activity and blood flow, and a positive correlation between Alpha activity (8-13 Hz brain waves that lie in the middle of the brain waves frequency band) and blood flow to the brain. In other words, when the client succeeds in maintaining a high Alpha state for some time, his/her brain receives more blood and therefore more oxygen and nutrition. This also stimulates impaired neurons to regenerate and improve their conduction of electric signals.

Bio-signal feedback technology can be interfaced with many high technology products for the aged and the young. This will form the basis for some form of preventive action to normal degeneration due to ageing. If the person is already familiar with such a technology, it will be easier to return to using bio-feedback as one ages or while recovering from stroke, injury, etc.

Human Machine Human Interaction (HMHI) for Collaborative Scenarios

Each one of us who has visited a rehabilitation clinic or ward will have etched in their minds images of lonely, dejected looking patients going through their paces by themselves, while the new patients get the major part of the attention from the overworked and outnumbered clinicians and therapists. Some studies have shown that de-motivation is one of the major reasons for patients stopping rehabilitation prematurely. Two acknowledged factors are progressively decreasing therapist contact and steadily decreasing rate of improvement leading to de-motivation (Damush, T.M., Plue, L., Bakas, T., Schmid, A. & Williams, L.S., 2007; Johnson, M.J., Feng, X., Johnson, L.M., Ramachandran, B., Winters, J.M., & Kosasih, J.B., 2006; Johnson, M.J., 2007). This scenario is in sharp focus now with an exponentially increasing disabled population. In 2007, the US added almost 2 million people to its number of disabled, covering stroke, TBI and hip fracture cases. The number of people with significant disability in the US alone now totals more than 10 million.

From this perspective, it may be beneficial to design the robotic rehabilitation devices to be multi-station systems instead of single station systems. Here two or more patients can play against or with each other, driving each other or even physically sharing strength and mobility resources to assist each other in exercise and functional movement (Figure 5). It is possible that this will go a long way to address both problems currently faced, namely de-motivation and cost. The patients may be chosen to pair up against each other in a way that they complement each other. Besides two or more patients sharing the same hardware will substantially reduce cost and therapist time.

Figure 5. An opportunity for HMHI-a device may assist in playing cards for those undergoing hand and wrist retraining with 2-4 stations

For example, a system like the MIT Hand Guide (Krebs H.I., Ferraro, M., Buerger, S.P., Newbery, M.J., Makiyama, A., Sandmann, M., Lynch, D., Volpe, B.T., & Hogan, N. 2004) the Gentle/s System (Loureiro, R.C.V., Johnson, M.J., Harwin, W.S., 2006) can be reconfigured so that one patient can assist the other to complete the movement correctly. The creators of the Gentle/s system acknowledge that cost and patient motivation are concerns. An exercise like the simple Peg Board can be configured with a slow conveyor so that two or more patients can compete or assist in a time trial over a fixed number of cycles with varying degrees of difficulty. Indexing work stations can take the patients on a musical chairs of performing varying Activities of Daily Living (ADLs) with each other eg. simulate making a sandwich.

A person with lesser disability can help a more disabled person. The performance of each may be recorded for future reference, analysis and assessment. We believe the ability to help a fellow patient will be a huge self esteem and motivation boost for a patient who has struggled with therapy for quite a few months (Maritz C.A., 2007). To the clinic it will mean less therapist load with a cost saving for both.

Community projects in some countries like Japan and Turkey have proved several advantages but patients may be in the same room and yet lonely and disconnected, especially if there is significant cognitive impairment. Engagement through multi-station devices is worth researching especially for those patients “in-need-of-care” and “quasi-in-need-of-care” states. Most stroke patients are elderly. We find worldwide across cultures, senior citizens feel motivated to come together in groups for recreation and socializing and travelling (Nawate, Y., Kaneko, F., Hanaoka, H., & Okamura, H., 2007).

Brain Entrainment

When we come to the question of bio feedback, the positive effects of this treatment modality is well established in people from all walks of life. Whether the user is a normal or disabled child, elite athlete, a normal or disabled adult or a senior citizen, we find that it helps them take charge of their lives. Hence, apart from the VAK pathways, bio-feedback is an important tool for engagement universally. Systems such as the Somaticvision combine gaming and bio-feedback to induce beneficial states and moods in persons (”How do skin conductance” n.d.). These beneficial moods forms the basis for the user engaging closely and longer with assistive and rehabilitative technology.

With the discovery of brainwaves came the discovery that electrical activity in the brain will change depending on what the person is doing. For instance, the brainwaves of a sleeping person are vastly different than the brainwaves of someone wide awake. Over the years, more sensitive equipment has brought us closer to figuring out exactly what brainwaves represent and with that, what they mean about a person's health and state of mind. This sensitivity is now available at a fraction of the cost compared to a decade ago.

You can tell a lot about a person simply by observing their brainwave patterns. For example, anxious people tend to produce an overabundance of certain (high beta) waves while people with very low attention tend to produce very low amplitude of alpha and beta waves. Researchers have found that not only are brainwaves representative of of mental state, but they can be externally stimulated to *change* a person's mental state, and even help treat a variety of mental disorders.

“Brainwave entrainment” refers to the brain's electrical response to rhythmic sensory stimulation, such as pulses of sound or light. When the brain is given a stimulus, through the ears, eyes or other senses, it emits an electrical charge in response, called a Cortical Evoked Response (Figure 6).

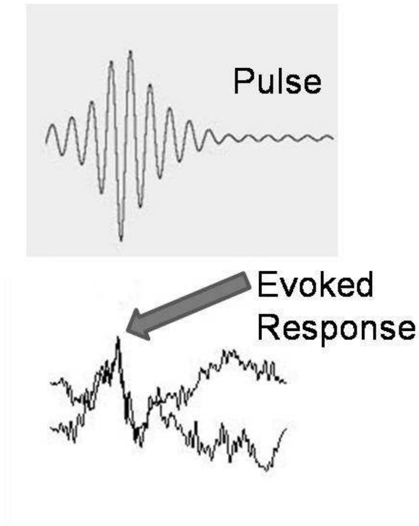

Figure 6. Reflection of external pulse in the EEG as an evoked potential.

When the brain is presented with a rhythmic stimulus such as a drum beat, the rhythm is reflected in the brain waves. If the rhythm becomes fast and consistent enough, it can start to resemble the natural internal rhythms of the brain, as seen in the EEG. When this happens, the brain responds by synchronizing its own electric cycles to the same rhythm.

Brainwaves are very much related to mental state. For example, a 4 Hz brainwave is associated with sleep, so a 4 Hz sound pattern would help reproduce the sleep state in your brain. The same concept can be applied to nearly all mental states, including attention, frustration, stress and many others. As the session progresses, the frequency rate of these pulses is changed slowly, thereby changing your brainwave patterns and guiding your mind to various useful mental states.

Brainwave Entrainment has been proven to have beneficial effects on the elderly disabled, especially in inducing 10Hz alpha waves which enhance short term memory and relaxed wakefulness (Williams, J., Ramaswamy, & D., Oulhaji, A., 2006). The pulses are usually audio or visual stimuli.

Adaptable Triggers for Multi-level Interfaces

Why use a single trigger type or a single muscle contraction to drive or operate an assist device? The disabled person, apart from his need to communicate, needs to be as active as possible with whatever muscles are at his command. This is critical for his survival. Otherwise over a period of time, muscle wastage will also hit the muscle that he has trained for triggering the device, since surrounding muscles are wasting. Hence it is important to use as many different muscle contractions as possible. A TV remote may thus be hooked up with a bio-signal electrode to switch every time there is a muscle contraction (on the forearm for example) or a reduction in heart-rate. This is very easily done with today's wireless technology and microelectronics. Or the TV may run for 60 seconds for every 15 seconds of pedalling for those who need lower limb exercise and mobility. Gadgets such as these can be used by everyone in the house to enhance performance, apart from the aged person. It is also preventive in function.

Such technology platforms will also enable simultaneous selection (eg. close eyes and raise eyebrows) of more than one trigger at the same time, thus speeding up a person's functions and enabling some level of multi-tasking, which is an important and much desired quality by humans. It gives them a feeling of efficiency and control.

In many brain-computer interface systems, the user has to continuously look at a navigation screen. It may be more practical to have a few muscle contractions dedicated for certain user defined actions (as we are doing with our UE orthosis) and have some contractions or brain signals act only as navigation tools (e.g. wheel chair and PC).

While many papers present valid engineering ideas, few address the clinical point of view. Clinically, those muscles should be used for generating trigger signals which most need to be exercised! Then we have enhanced rehabilitation. Else the patient becomes an expert at communicating but his physical condition deteriorates due to disuse of some body parts. This is a key point that we feel no new human-machine interface adequately addresses. What muscle group is the patient using for the device and what clinically does he really need to use?

If we make this one of the considerations for design, the spinoff for the patient is that even for passive activities, the person can have the option of exercising clinically important large or small muscles or muscle groups. This will ensure that clinical requirements related to muscle disuse, overuse and co-ordination can be addressed through the device, even outside the therapy session eg. Monitoring EEG to automatically slow down a car if the driver is in danger of an impending epileptic seizure or stress level is rising. We feel having such an option is a key step to integrate the patient better to the device and make the device a part of everyday life, thus leading to extended use and more repetition.

A Unified EEG/SEMG Platform for Operation of Assist/Rehab/Play Devices

Results of some of the SEMG and EEG experiments by the authors were reported earlier last year (Heng, J., Banerji, S., 2009). The unified EEG/SEMG platform is sensitive to changes in SEMG and EEG differences and these changes can be used to trigger a motor or some other actuator in an assist device, in a collaborative or individual manner. A pictorial representation of the Unified Platform concept is shown in Figure 7.

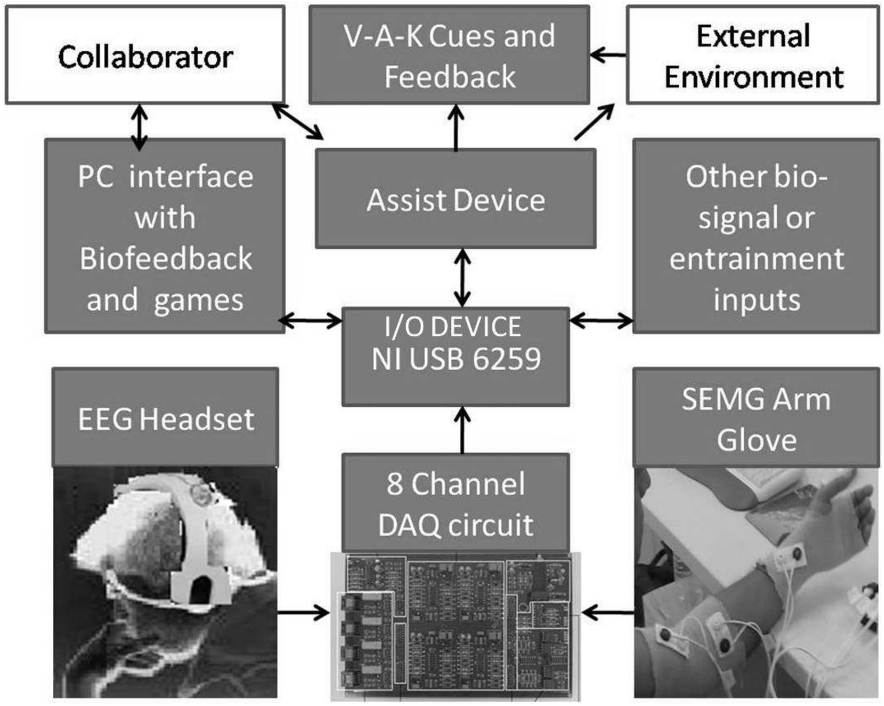

Figure 7. Schematic representation of a plug-n-play system which engages the internal and external environments of the user

Recording the SEMG provides the immediate activity triggers while the quantitative EEG analysis periodically updates and illustrates the brain states. The game or device for individual and collaborative use can be based on voluntarily altering the SEMG and brain waves towards more optimum values. The twin purposes of training the mind-body internal environment and operating functional or play/work devices in the external environment are thus, both met.

A. Sharing resources through HMHI for SEMG

The use of muscle contractions in the real time operation of switches and motors was tested in several formats. One of these was the combining of SEMG from muscle contractions of two persons to achieve a simple task. Figure 8(A) below shows the difference in contraction strength of two healthy young adult persons using the same muscle. The small and large amplitude generation in this case was voluntary. One person tried to pull the pointer on the scale to the left (zero on the scale) while the other tried to pull it towards the right (6 on the scale).

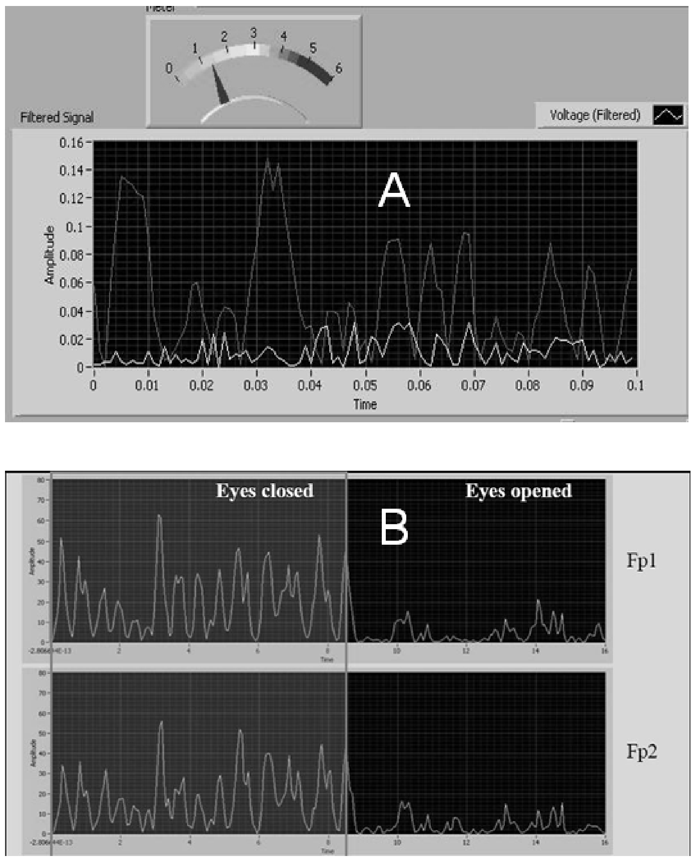

Figure8. A. LabView front panel showing simultaneous processing of signals from two persons B. Alpha wave increase detected during eyes closure

The algorithm was further modified so that it could generate real-time statistical triggers even with small twitches of intrinsic forearm muscles like finger flexors and extensors, showing sensitivity even with dry, button electrodes.

The unified neuro-physio platform has the analog and digital ports to communicate with the proposed assist device, using the person's ability to control his SEMG and sharpen his kinesthetic perception, using both bio-feedback in solitary play and strength and timing feedback in collaborative play. This will increase confidence in interaction and team work for simple, guided tasks. At a later stage, it may facilitate the ability to play and train with another person freely, as well as set their own game parameters.

The data acquisition system can also accept other inputs like those from force and motion sensors, if these are incorporated into the proposed 3-dimensional assist or play device.

B. Interacting with the assist device using EEG and facial expression

In the development of an "Active" assist device for which the sub-system is being designed, the use of quantitative EEG analysis is significant for detection of certain triggers and mental condition of the patient (R.J., Clarke, A.R., Johnstone, S.J., Magee, C.A., & Rushby, J.A., 2007; Van Putten, M.J.A.M, Tavy, D.L.J. 2004). In most quantitative EEG applications, the frequency content of the signals is the most important parameter of interest. Hence, even if the EEG circuit could detect the main frequency contents of the test signal satisfactorily, it could still be used to activate the play object, both in order to elicit a response from another child, or as "on-the-go" bio-feedback.

Even if qualitative signal acquisition and display is not noise free at present, we find it is possible to tap into some EEG signals from the forehead using the EEG electrodes which are repeatable enough to act as triggers for certain functions. This is illustrated in figure 8(B).

During the experiment some muscle artifacts were also recognized by the recording instrument. Some apparent artifacts were recorded when the person was squeezing his eyes in eyes close and open position as well as blinking. Muscle artifact due to eyes squeezing in eyes open and close condition resulted in predicatable signal detected in gamma wave band. It was found that not all of the wave bands were significantly affected by the muscle artifacts.

Ultimately, the ability to combine inputs from multiple sources such as SEMG, EEG, pressure transducers, goniometers, motion sensors, etc. will enable a level of multi tasking not seen in assistive technology so far. The hardware and software development for such a system in a wireless format will be a useful pursuit for the future.

A multi-level interface which is robust, easy to set-up, versatile, adaptable and of low complexity increases the possibility of having a portable, miniaturized system with several interaction levels,

Level 1	-the direct physical input eg. Keyboard, mouse, joystick, etc.
Level 2	-the secondary input eg. Head tracking, eye tracking.
Level 3	-the neuro and muscle input eg. EEG, SEMG.
Level 4	-the involuntary bio-signal input eg. Heart rate, respiratory rate, etc.

Used simultaneously for operating various devices and self-training through the feedback loop, this will effectively bridge the users' internal and external environments.

FUTURE VISION

In the course of the next decade, we shall probably have a cochlear implant which will enable people to hear better than normal by being sensitive to a wider frequency range. The artificial eye promises to not only enable the visually impaired to recognize faces, but to see in the ultraviolet and infra red range. If this happens, high tech AT will move into the area where normal people will also want to use it!

Usage will increase as designs become more universal and collaborative. Acceptance after onset of disability will increase if the person has experienced the technology prior to the disability. Being familiar with the process of entrainment and alignment, people will fend off advancing age much better than they do now. Furthermore, a large population of people will be ready and capable of retraining themselves and making the adjustments one needs to as one ages, with and without physical devices, both in the internal and external environments.

The body focused mechanistic approach that most technologies have adopted today has influenced the way people perceive assistive technology. It is within the capabilities of AT as we know it today to not only help people lead better lives, it can also revolutionize how people perceive health and well-being, well before the onset of disability. This is possible if the technology encompasses both the inner and outer worlds of the user.

If we can do that, AT will be as widely used as probably a TV set. Every member of the family will use it, just by switching channels to start individual customized programs. Accessibility will be driven by the demand for AT (as it has been driven by the demand for the internet), and not the other way around.

CONCLUSION

Building into the basic design a capability of HMHI (Human- Machine-Human Interaction) moves the user away from "Isolation" to a more "Relational" environment, where he or she is able to interact with a living being at various levels. From this perspective, it may be beneficial to design a plug-n-play technological platform that allows the user several options in a seamless manner:

1) Allow sharing of resources such as strength, mobility and motivation between two or more aged persons

2) Allow use of the system in multiple environments, so that it is usable for all levels of impairment and fatigue as well as facilitates more variety in activity

3) Gives elders a chance to integrate with the system at multiple levels with their residual functions, so that they can adjust, communicate and respond faster.

If a device reinforces an aged person's inner resources (e.g. improves self image, confidence, allow social inclusion) it will be a great means of attracting the elderly to use the device. This applies to those who wish to show the world that they are independent as well as those who are more comfortable being dependent physically on someone else, but value interdependence.

Along with principles of universal design, this new paradigm of design can be the springboard for a new generation of simple, universally used assistive devices which can integrate seamlessly with the user. The graded sensitivity of such devices to the user's needs, rather than merely its level of intelligence, will enable higher usability and help the aged to integrate with society and the environment.

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ADDITIONAL READING MATERIAL