Accessible Design Criteria

Universal Design

Universal design is the design of products and environments to be useable by all people, to the greatest extent possible, without the need for adaptation or specialized design. There are seven main principles of universal design [22]:

1. Equitable Use – The design is useful and marketable to people with diverse abilities.
    - Guidelines includes providing the same means of use for all users, avoiding segregating or stigmatizing any users, provisions for privacy, security, and safety easily accessible by all users, and making the design appealing to all users.

2. Flexibility in Use – The design accommodates a wide range of individual preferences and abilities
    - Guidelines includes providing choice in methods of use, accommodating left- or right-handed access and use, facilitating and user's accuracy and precision, and providing adaptability to the user's pace.

3. Simple and Intuitive – Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
    - Guidelines includes eliminating unnecessary complexity, being consistent with the user's intuition and expectation, accommodating a wide range of literacy and language skills, arranging information consistent with its importance, and providing effective prompting and feedback during and after task completion.

4. Perceptible Information – The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
    - Guidelines includes using different modes (pictorial, verbal, tactile) for redundant presentation of essential information, providing adequate contrast between essential information and its surroundings, maximizing "legibility" of essential information, differentiating elements in ways that can be described, providing compatibility with a variety of techniques or devices used by people with sensory limitations.

5. Tolerance for Error – The design minimizes hazards and the adverse consequences of accidental or unintended actions

    - Guidelines includes arranging elements to minimize hazards and errors, providing warnings of hazards and errors, providing fail safe features, and discouraging unconscious actions in tasks that require vigilance.

6. Low Physical Effort – The design can be used efficiently and comfortably and with a minimum of fatigue.
    - Guidelines includes allowing the user to maintain a neutral body position, using reasonable operating forces, minimizing repetitive actions, and minimizing sustained physical effort.

7. Size and Space for Approach and Use – Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, and mobility.
    - Guidelines includes providing a clear line of sight to important elements for any seated or standing user, making reach to all components comfortable for any seated or standing user, accommodating variations in hand and grip size, and providing adequate space for use of assistive devices or personal assistance.

It is important to note that these principles of universal design address only universally usable design, while the practice of design involves more than consideration of mobility. The design team must also incorporate other considerations such as economic, engineering, cultural, gender, and environmental concerns in our design processes.

Mainstream Considerations

From above, considering those with functional limitations in the overall design process is good for the design process overall. Design which is more accessible to persons with disabilities typically can benefit able-bodied users as well by reducing fatigue, increasing speed and decreasing the number of errors made. One example is to be found in elevator design. Individuals in wheelchairs or on crutches had great difficulty with the large "banks" of elevators present in many buildings. Often the elevator door would open, but before the person in a wheelchair could get to the correct elevator, the door would close. An obvious solution would be for the elevators to stay open for a longer period of time. However, building codes required that a building's floors be visited by the elevators with a specified frequency. If the doors were made to stand open longer, additional elevators would need to be installed in the building to meet the level of service standards. In a building like the Sears Tower, this could result in a substantial portion of the building being consumed by elevators.

Creating more accessible designs can also increase the market for many consumer products. With increasing awareness of the accessibility issues, people are beginning to look for more accessible designs. The U.S. government, for example, has recently passed legislation (Section 508 of Public Law 99-506) requiring that the General Services Administration develop accessibility guidelines that should apply to all future electronic office equipment acquisitions (purchase or lease). Similar measures are being examined by other countries as well as many school systems and state governments in the U.S.

Accessibility features should begin to provide a market edge even in the home market. Although only one in five or six individuals in the United States has a significant functional limitation, a much higher percentage of households have individuals who have functional limitations. Products purchased for use in a household that has even one member with a disability may be more attractive if their design is more accessible. More accessible design will also increase the useful product life of many products purchased by or for individuals who are aging.

95th Percentile Illusion

It should be clear that even if elderly and disabled persons are included in the mainstream design process, it is not possible to design all products and devices so that they are usable by all individuals. There will always be a "tail" of individuals who are unable to use a given product [22].

In order to include a sizeable portion of the population in the category of "those who can use a product with little or no difficulty," the 95th percentile data are often used. The problem is that there are no "95th percentile" data for specific designs. Rather, there are only data with regard to individual physical or sensory characteristics. Thus there is 95th percentile data for height, a 95th percentile for vision, hearing, etc. As a result, it is not possible to determine when a product can be used by 95% of the people. It is only possible to estimate when a product can be used by 95% of the population along any one dimension. Since people in the 5% tail for any one dimension (e.g., height) are usually not the same people as the 5% tail along another dimension (e.g., vision) [10], it is possible to design a product using 95th percentile data and end up with a product that can be used by far less than 95% of the population. To illustrate this phenomenon, imagine a mini-population of ten individuals. Ten percent of them (1 of 10) have one short leg, 10% have a visual impairment, 10% have a missing arm, 10% are short and 10% cannot hear.

Let's assume that we design a product that required 90th percentile ability along each of the dimensions of height, vision, leg use, arm use, and hearing. In this instance we would end up with a product which was in fact only usable by 50% of this population. This occurs because, although only 10% of this mini-population is limited in any single dimension, different individuals fall into the 10% tail for each dimension and only 50% of the population is within the 90th percentile for all five areas.

In real life, the effect is not quite this dramatic, and its calculation is not so simple. First, the percentage of individual with disabilities is less than 10% along any one dimension. Secondly, there is often overlap where one individual would have more than one disability (elderly individuals, for example). On the other hand, there is a much wider range of different individual types of disability. In addition, the data from which the 95th percentiles are calculated often exclude persons with disabilities [10], making the percentage who could use the design(s) smaller than one would first calculate.

EZ Access

EZ Access combines simple interactive techniques in ways that work together robustly and flexibly to accommodate users. This allows more people to use the product, according to their own ability, preference, or circumstance. For example, a product that has only a touch screen may be difficult or impossible for many people to use. With the addition of just a few buttons and voice output, the product becomes usable by people who cannot see, cannot read, cannot reach the screen, or cannot make fine movements with their arms, hands, or fingers. The addition of captions further extends the product to people who cannot hear (Figure **).

(a)

(b)

Figure **: **(a)** 5 button EZ Access keypad [22]. **(b)** 8 button EZ Access keypad [22].

The EZ access includes features such as Voice + 4 button navigation which give complete access to any onscreen controls and content. This feature also provides feedback and information in a logical way such that it can be used by both sighted and non-sighted users. Typical items include onscreen text, images and controls. The

Touch Talk lets users touch onscreen text (and graphics), to hear them read (or described) aloud. Button Help provides a way for users to instantly identify any button on the device. At any time, a person can see and/or hear any button's name and status. They can also get more information about what that button can be used for. Layered Help provides context sensitive information about using the device. If a person needs more help, they can press the help button repeatedly, receiving more information each time. Lastly, ShowCaptions provides a visual presentation of any text or sounds created by the device that is not already visually displayed.

Accessible Design Principles

Two members of the design group enrolled into a one semester biomedical course dealing with the design of products for persons with physical, hearing, sensory or cognitive impairments as well as the design of standard mass market products. Through this course, we became knowledgeable about the different types of impairments and designed ways to solve these problems. We have applied these concepts into the design of the ergometer to make it more accessible to persons with different disabilities. The disabilities addressed in the design of our prototype include: low vision, blind, deaf, Parkinson's disease, stroke, heart failure, and diabetes. For each of the disabilities listed above, a thorough description of that disease will be given followed by techniques that can be implemented to improve accessibility to those with that disability in using an ergometer. The majority of the information presented in this section was found on the University of Wisconsin Trace Research and Development Center website (http://trace.wisc.edu/) [22].

Low Vision

When vision degrades significantly below normal and begins to cause difficulties seeing and carrying out activities that require sight, it is referred to as *low vision*. Visual impairments can take on a wide variety of forms, including blurred vision, hypersensitivity to glare, tunnel vision, peripheral vision, etc. It can also vary from mild visual impairment to total blindness. Some interventions, such as cataract surgery, can restore sight but still have visual side effects such as reduced focal range. As a result, the problems faced by people with visual impairments vary greatly from individual to individual, as do the particular strategies and assistive technologies that they would use.

People with low vision can often increase their visual ability simply by increasing the light level. Increased light level not only helps individuals with visual acuity problems, but also helps individuals with night blindness or lack of light sensitivity. For individuals with sensitivity to glare, the use of diffuse light as well as adjustment of their position relative to windows or other sources of bright light can greatly facilitate their general vision in carrying out a given task. For increasing readability of printed characters, having a high contrast between the printed characters and the background increased their readability, as does using typefaces that have a wider stroke.

Computer access strategies for people with low vision primarily involve the enlargement of text. With the advent of graphics-based computers such as the Macintosh and Windows operating systems, the problem of screen enlargement has become easier. Because these systems use pixel-based character display, it is fairly easy to create software that will simply increase the size of the pixels, thus enlarging the image on the screen. This technique results in large letters, up to 16 times normal size, or more. Also, basic screen pan and zoom capabilities can be built into these graphics-based systems, providing at least basic screen enlargement capabilities as a standard part of the system.

For the use of appliances for people with residual vision, a primary strategy is to remember the locations and functions of controls. For devices having scales or legends that must be read, applying large, high-contrast, broad-stroke lettering or labels over the top of the existing labels is often done.

Blindess

As a person's vision gets so bad that it is of limited use, we begin to refer to the impairment as *blindness*. The most useful definition of blindness is "a condition in which a person has lost the use of vision for ordinary life purposes, although some residual vision may exist." *Legal blindness* is defined as visual acuity (sharpness of vision) of 20/200 or worse in the better eye, after correction, or when the field of vision is less than 20° in the better eye, after correction. An important point worth noting is that many (but not all) people who are "blind" can see something. In other words, they may not see only blackness, but may be able to tell the difference between extreme light and dark conditions, or may have more, but still very limited, visual ability. They key thing that differentiates blindness from low vision, however, is that with blindness vision is so poor that it does not meet most of life's needs. When designing products for people who are blind, it is important to make provision for gross visual cues (e.g., large white buttons on a dark background or the use of color) to benefit people with some minimal residual vision.

For individuals who are unable to read text visually, a number of tactile strategies have been developed. By far the best known is the use of Braille. Braille is a tactile code developed by Louis Braille to represent the letters of the alphabet. There are six dots in a Braille "cell." The different characters (letters) are formed by the presence of one or more of these six dots. Unfortunately, only about 10% of the people who are blind prefer to use Braille. This is due to a number of factors, but primarily because many individuals lose their sight later in life, when learning Braille is more difficult. Also, some individuals lose the sense of touch in their fingertips at the same time they lose their sight (e.g., from diabetes) and are unable to learn or use Braille. Another tactile mechanism for reading is the use of raised letters. Although this strategy can be used for short labels, it is not generally useful for reading text. In order for letters to be recognized tactually, they must be quite large and fairly distinct.

For people who are blind, the primary computer access techniques have involved screen readers. With these software/hardware products, users can have the characters, words, and blocks of text on the screen read aloud using synthetic speech. With the advent of Acrobat Reader 6.0, Adobe has embedded a screen reader of sorts into the Reader software itself. This scaled-down version of a screen reader (more accurately referred to as a text-to-speech synthesizer in this instance) can read aloud the text in nearly all PDF files, even older files that were not created with accessibility in mind [2].

Deafness

In discussing hearing impairments, it is useful to distinguish between deafness and less severe hearing loss. *Deafness* is a profound degree of hearing loss that prevents understanding of auditory information, including speech, through the ear. Normal conversation is approximately 40 to 60 decibels in volume. A person is usually considered deaf when sound must reach at least 90 decibels to be heard at all, and even amplified speech cannot be understood.

People with hearing impairments rely much more heavily on sight as well as vibrations for environmental awareness. Unfortunately for these individuals, today many warning and alerting systems are based solely on sound. For individuals who are totally deaf, however, a mechanism that does not depend upon sound is necessary for signaling an emergency situation. This mechanism could include:

1. Small visual indicator or change in the device's display
2. Turning on an environmental light
3. A bright strobe light or flasher
4. Vibration of a device in contact with the individual
5. Vibrating the environment

In general, hearing impaired users do not have a hard time using certain devices such as computers as along as any audio output is coupled with text that appear on the monitor.

Parkinson's disease

Parkinson's disease belongs to a group of conditions called motor system disorders, which are the result of the loss of dopamine-producing brain cells. The four primary symptoms of Parkinson's disease are tremor, or trembling in hands, arms, legs, jaw, and face; rigidity, or stiffness of the limbs and trunk; bradykinesia, or slowness of movement; and postural instability, or impaired balance and coordination. As these symptoms become more pronounced, patients may have difficulty walking, talking, or completing other simple tasks. Parkinson's disease usually affects people over the age of 50. Early symptoms of Parkinson's disease are subtle and occur gradually. In some people the disease progresses more quickly than in others. As the disease progresses, the shaking, or tremor, which affects the majority of Parkinson's disease patients may begin to interfere with daily activities [15].

When trying to provide effective and efficient interface techniques for people with physical impairments, the first step is to make sure they are able to fully utilize their current physical abilities. Similarly, people who are weak or who have muscle activities that interfere with their control may require stabilizing in order to effectively and efficiently use different interface techniques. The first component of optimal physical control is a stable platform. A person's trunk needs to be stable in order to have maximum control of the limbs. The most important component of an interface, therefore, is proper and stable seating or positioning. Also, people with Parkinson's disease sometimes have a hard time initiating motion. Implementing a target for them to achieve has been shown to be beneficial for this impairment.

People with Parkinson’s disease tend to have tremors and may cause multiple key activation when using a device. To eliminate spurious key activation, placing a delay on the key acceptance time would be beneficial. A key would then have to be held down for some length of time before it would be accepted (e.g., ½ to 1 second). If an individual accidentally bumped a key on the way to the desired target, it would be ignored since it would not be held down for the required time. When the desired key is pressed, it would have to be held down for the required time before being accepted. When used on a keyboard, the delay activation feature is commonly called “SlowKeys.”

Some people have difficulty removing their hand from a control without activating it a second time. A technique to surmount this type of movement and allow them to operate buttons more successfully would be to introduce a period of time after a button is released during which further input on the same button would not be processed. This would eliminate dual activation if the individual bounced while either pressing a button or releasing it. When used with keyboards, this feature is often called “BounceKeys.”

Stroke

The three main causes of stroke are: thrombosis (blood clot in a blood vessel blocks blood flow past that point), hemorrhage (resulting in bleeding into the brain tissue; associated with high blood pressure or rupture of an aneurism), and embolism (a large clot breaks off and blocks an artery). The response of brain tissue to injury is similar whether the injury results from direct trauma or from stroke. In either case, function in the area of the brain affected either stops altogether or is impaired. In some instances, the individual is left with limited movement in the lower limbs, upper limbs, or one complete side of the body.

To allow individuals with motion limited to one side of the body to exercise, the arm motion should be right and left side independent. This would allow users to workout their functional arm without the need to use their impaired arm. Other solutions to this kind of physical impairment parallel with key ideas addressed above in the Parkinson’s disease section.

Heart Failure

Heart failure is a progressive disorder in which damage to the heart causes weakening of the cardiovascular system. It is clinically manifested by fluid congestion or inadequate blood flow to tissues. Heart failure progresses by inappropriate responses of the body to heart injury. Heart failure may be the sum of one or many causes. It is a progressive disorder that must be managed in regard to not only the state of the heart, but the condition of the circulation, lungs, neuroendocrine system and other organs as well. Furthermore, when other conditions are present (e.g. kidney dysfunction, hypertension, vascular disease, or diabetes) it can be more of a problem. Finally, the impact it can have on a patient psychologically and socially are important as well [1, 7].

To ensure the safety of users with heart failure, CardioGrip™ Heart Rate Sensors were placed on the arm handles of the seat. By allowing the user to monitor their heart rate, they will be able to determine how hard they are working their body and prevent themselves from overexertion. Other possible solutions to this kind of physical impairment also parallel with key ideas addressed above in the Parkinson's disease section.

Diabetes

Diabetes is a problem with the body's fuel system. It is caused by the lack of insulin, a hormone made in the pancreas (an organ that secretes enzymes needed for digestion) that is essential for getting energy from food. There are two kinds of diabetes:

- In type 1 diabetes, which usually starts in children, the body stops making insulin completely.
- In type 2 diabetes, also called adult-onset diabetes, the body still makes some insulin, but cannot use it properly.

Most adults with diabetes have type 2; in fact, type 2 diabetes accounts for 90 percent of all diabetes cases [23].

Here's how insulin works. Food is digested in the stomach and intestines, and carbohydrates are broken down into sugar molecules, or glucose. Glucose is then absorbed into the bloodstream, and blood glucose levels rise. This rise in blood sugar normally signals special cells in the pancreas, called beta cells, to release the right amount of insulin. Insulin allows glucose and other nutrients (such as amino acids from proteins) to enter muscle cells. There, they can be stored for later use or burned for energy. When the body has a problem making insulin or the cells do not respond to insulin in the correct way, diabetes results.

One of the common symptoms found with people with diabetes is blurred vision. Techniques such as providing large lettering with high contrast between black and white is beneficial to such users. In addition, some people with diabetes lack the ability to tactically differentiate between various surfaces due to the onset of neuropathy, a complication in which the peripheral nerves degenerate and the sense of touch is diminished or lost. To overcome this, large buttons with distinct corners and contrasting colors will benefit diabetic users.