# ERGONOMICS for REHABILITATION PROFESSIONALS

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CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742


Printed in the United States of America on acid-free paper
10 9 8 7 6 5 4 3 2 1

International Standard Book Number-13: 978-0-8493-8146-1 (Hardcover)



**Library of Congress Cataloging-in-Publication Data**

Ergonomics for rehabilitation professionals / Shrawan Kumar.
p. cm.
Includes bibliographical references and index.
ISBN 978-0-8493-8146-1 (alk. paper)
1. Medical rehabilitation. 2. Human engineering. I. Kumar, Shrawan. II. Title.

RM930.E74 2009
617'.03--dc22 2008043677

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# 4 Aging and Ergonomics

*Lili Liu and Robert Lederer*

## CONTENTS



## 4.1 INTRODUCTION

This chapter provides an overview of the demographics of aging and provides a revised definition of "old." The changing demographics have implications for current and future roles of rehabilitation professionals. In the past, rehabilitation focused on addressing the needs of populations with disabilities. With the aging of the baby-boomer population, most of whom will remain in the community, the focus of rehabilitation will shift from disability to the needs of older people who may or may not have a combination of disabilities. Concurrently, there is a movement focusing on environmental design as an approach to facilitating function in seniors who may or may not yet have limitations. In other words, given the right environment, product, or even service design, some disabilities would no longer be issues.

Ergonomics and human factors are examined from the perspective of age-related changes in physical, sensory, and cognitive functions. These changes are reviewed and some design recommendations for addressing these are provided. Next, we discuss the emerging role of rehabilitation professionals in design for aging and provide four examples of products designed by students in Occupational Therapy and Physical Therapy in collaboration with students in Industrial Design at the University of Alberta. These teams also included older adults in the design process. These award-winning designs emphasize the necessity of teamwork and interdisciplinary collaboration. We conclude with an example of the role of a rehabilitation professional as a leader in the conceptualization, design, usability testing, and clinical trial for a commercial version of an e-health wireless sensor technology. Throughout the design phase, ergonomic and human factors were considered in the context of usability of this technology for older adults living in the community.

## 4.2 DEMOGRAPHICS AND THE DEFINITION OF "OLD"

In Canada, close to 19% of the population will be 65 years or older by 2021, up from 12.3% in 1998.[1] The proportion of seniors in Canada will be four times as high as it was a century before.[1] The first of the baby-boomer generation, those born between 1947 and 1966 (or from 1946 to 1964 in the United States), will reach 65 years in 2012 (2011 in the United States). This group forms 32.4% or the largest proportion of the Canadian population.[2] In the United States, close to 36 million, or 12% of Americans, are aged 65 years or older. This is projected to increase to 72 million, or 20% of the U.S. population in 2030.[3] Globally, there are over 600 million people aged 60 years and older[4] (WHO, 2002). This will increase to 1.2 billion by 2025 and 2 billion by 2050.

It has been argued there is a need to revise our definition of "old." Based on computations using life tables over four decades, Denton and Spencer[5] demonstrate that if 65 years of age was accepted as old in 1951 for males, the definition should be revised to be about 68.5 years of age in 1991. If 65 years was viewed as a male-oriented definition of old in 1951, the corresponding definition for females should be 67.5 years of age in 1951, and 73 or 73.5 years of age in 1991.[5] Given the longer life span of both men and women over the last four decades, and the aging of populations globally, there will likely be an increasing number of older adults staying healthy and working beyond the age of 65 years.

## 4.3 ERGONOMICS AND OCCUPATIONAL PERFORMANCE

This shift in demographics requires a shift in environmental and product designs. The discipline of ergonomics has traditionally examined the fit of the workplace environment and the ability of human beings to perform safely and productively within that environment.[6] This focus of ergonomics excludes most older adults who are going through the transition from work to retirement, or who have retired but are still engaging in a productive role. They also form a large segment of the consumer population that demands well-designed products. Work or productivity is more appropriately considered in the context of "occupational performance," defined as an individual's experience of being engaged in self-care, productivity, and leisure,[7] or consisting of activities of daily living, instrumental activities of daily living, education, work, play, leisure, and social participation.[8] Although older adults may engage in work beyond 65 years, occupational performance within an older population encompasses activities beyond paid employment. These activities may be productive work performed on a part-time or volunteer basis, or they may be leisure and social activities. Older adults may choose or find themselves in caregiving roles for young children, or other older adults such as spouses, neighbors, and friends.

## 4.4 MOST OLDER ADULTS LIVE IN THE COMMUNITY

The majority of seniors live at home. In 2001, only about 9% of older women and 5% of older men in Canada lived in institutions and these proportions have declined since 1981.[9] Successful programs and designs meet the needs of seniors who form a major consumer base and address their quality of life in the community. There is great variability between seniors in terms of their levels of occupational performance. While one cannot always assume that a senior experiences challenges, it is prudent to consider the needs of as many clients or users as possible so that the process of aging and "future needs" are considered. This approach has been referred to as a "transgenerational" or "universal design" approach.

- *Consumer base*: The boomers, because of their sheer number, have had a large impact on sale of products, and their needs and lifestyle will continue to drive retail product sales. As the boomers age, they will encounter age-related physical, sensory, and cognitive conditions, as their parents are experiencing today. This experience in caring for their parents is having an impact on their expectations for their own "golden years."
- *Quality of life*: Tomorrow's seniors will be different from today's seniors. It is predicted that, as a whole, the boomers will have more discretionary funds, be more comfortable, and have better access to technologies, and the gender gap will not be as wide as today. There will also be various retirement schemes available to tomorrow's seniors. All of these factors contribute to a cohort of seniors who will have more control over their quality of life compared to today's seniors.
- *Transgenerational approach and universal design*: If we design our products and environments for older adults, we also design for our future selves and multiple generations benefit. A universal design approach also takes into consideration interactions between seniors and younger children, as well as seniors and their care providers who also have ergonomic needs.

## 4.5 AGE-RELATED CHANGES IN PHYSICAL, SENSORY, AND COGNITIVE FUNCTIONS

Rehabilitation professionals understand the physical, sensory and perceptual, and cognitive changes associated with aging. This aspect of their education and training makes them ideal members of a design team. Rehabilitation professionals, such as occupational and physical therapists, can serve as team members or consultants in opportunities such as home renovations for seniors, design, and postoccupancy assessments of residential care facilities. Health professionals who work with older adults routinely consider ergonomic factors when they perform assessments and provide interventions for this population. However, few therapists participate in the design of products and environments used by older adults. By using their gerontology expertise to inform builders, architects, designers, and policy makers, rehabilitation professionals can help ensure that designs meet ergonomic requirements of seniors. As the baby-boomer population begins to reach the age of 65 years in the next 5 years, there will be an increase in demand for rehabilitation professionals to provide services in the community for this population. It is anticipated that rehabilitation professionals will play a more important role in providing guidance to their clients on decisions regarding home modifications and other strategies to allow seniors to age-in-place. Common age-related changes are now discussed with design implications.

### 4.5.1 Physical Changes

There is heterogeneity among older adults with regard to physical function. Extrinsic and intrinsic factors contribute to the effects of aging on a person's physical abilities. Extrinsic factors include exercise, nutrition, physical injuries; intrinsic factors include one's genetic makeup and susceptibility to diseases. Typically, aging is associated with a change in muscle strength, endurance, flexibility, posture, and gait.

Lower extremity muscle strength can decline by up to 40% between 30 and 80 years of age.[10] In one study based on 275 participants ranging in age from 30 to 86 years, researchers found that quadriceps muscle strength declined with age and that forward shift of the center of pressure also decreased.[11] This is believed to be the reason that some older adults experience difficulty with sit-to-stand movements from a chair. This movement may be easier with quadriceps strengthening and education on how to get up from a chair. However, it is also important to address environmental factors. For example, clients should use chairs that are the right size for their height and chairs should have armrests, which can be used by the client to push up when doing a sit-to-stand movement. Indeed, it has been found that the timed "Up and Go" test is dependent on chair type and that chairs with armrests and seating heights of 44–47 cm are recommended.[12]

Endurance, or the capacity of muscle to contract continuously at submaximal levels, declines with age.[10] This can affect rehabilitation assessment outcomes. For example, if a client is required to perform maximally during an assessment, the outcome may not reflect the client's actual functional ability during the remainder of the day when energy level or endurance has declined. In a study on the necessity of three trials for the Functional Reach Test, researchers concluded that scores based on one trial, two trials, or the average of two trials for a Functional Reach Test Score were not significantly different from the scores obtained from standard three-trial averages.[13] Therefore, fewer trials during this type of assessment may adequately reflect a client's performance.

Reduced flexibility can occur as a result of biology, hypokinesis (inactivity), or disease, such as arthritis.[14] A decline in strength and spinal flexibility result in

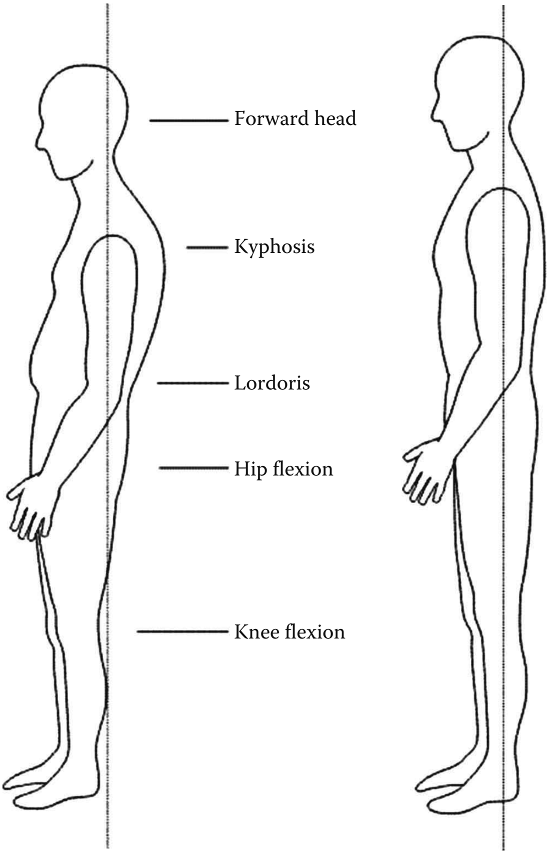


**FIGURE 4.1** Posture changes with age. (Illustration with permission from Chris Maley was adapted from Bernstein, C. in *Posture Changes with Age*, F.A. Davis, Philadelphia, PA, 2002.)

postural changes in older adults[10,14] (Figure 4.1). The forward posture of the head and kyphosis reduce the range of upward gaze in older adults. Kinematic data has shown that aging is associated with diminished ankle range of motion or reduced plantar flexion excursion during push-off, and reduced knee extension at the end of swing.[15] In a study on kinematics of stair decent using a three-step stair, researchers reported that stair decent was significantly slower in older subjects compared to younger subjects.[16] Other age-related differences were a reduced peak knee flexion in the sagittal plane, and increased hip and pelvic motion in the frontal and transverse planes, i.e., motion outside the plane of progression. These age-related differences did not change after exercise training three times a week for 12 months.[16]

#### 4.5.1.1 Upper Extremity Coordination

Reaching movements such as repetitive tapping tasks can slow down by 30%–90% with aging according to different studies.[17] This can be attributed to various factors including visual motor processing, central motor processing, and attention. Declining upper extremity strength and endurance may also be factors. Manual dexterity is also affected by aging and the effects can be seen in tasks such as tying shoelaces and fastening buttons.[17] While these age-related changes are observable under experimental conditions, especially when time is used as a variable, they typically do not affect healthy older adults in their daily functional activities.

Design considerations for age-related physical changes:

- Provide benches at regular distances in public spaces to allow older adults to rest.
- Entrance to public washrooms could be designed to allow a variety of mobility aids. Automatic sliding doors and entrances with no door (Figure 4.2) are common in airports. These accommodate the needs of older adults with mobility aids as well as travelers and their luggage.
- In homes, a space under the kitchen sink allows an older adult to work at the sink in a seated position (Figure 4.3). This design also works for wheelchair users.
- Evaluations and assessment batteries used with older adults should cause minimal burden on the client being assessed. If protocol allows, evaluation sessions may be divided to be conducted over two or more sessions.
- User-interface of electronic equipment, such as telephones and household appliances, should be user-friendly and logical to older adults.
- Location and height of signage should take into consideration lower upward gaze due to postural changes.

**FIGURE 4.2** Door-free entrance to washroom facilitates use by people who have mobility aids and travelers with luggage. (Photo taken by Liu, L., 2004.)

**FIGURE 4.3** Junichi Hashimoto, an Edmonton architect, demonstrates use of roll-in seat at kitchen sink located in Hokkaido's Asai Gakuen University Universal Design Show Home. (Photo taken by Liu, L., 2004.)

### 4.5.2 Sensory and Perceptual Changes

#### 4.5.2.1 Vision

In 2003, approximately 3 million Canadian seniors, or 82% of individuals 65 years or older, reported having vision problems.[18] Under normal lighting conditions, twice as much light is required at age 40 years as at age 20 years and three times as much at age 60 years.[19] Aging is associated with reduced visual field size, visual acuity, contrast sensitivity, increased sensitivity to glare and poorer color discrimination.[20] Cloudier lenses, smaller pupils, and fewer rods in the aged eye result in reduced amount of light reaching the retina. Changes in color perception are more evident after the age of 60 years.[21] The reception of short wavelengths (blue) are affected first, then gradually the rest of the spectrum, but the reception of long wavelengths (red) remain relatively unaffected.[21] Yellowing lenses cause seniors to experience difficulty discriminating between color combinations of yellow/white, blue/green, dark blue/black, and purple/dark red.[22] Older adults require more time than younger adults to adapt to darkness.[23] For example, for older adults in their seventies, the point at which rods take over is delayed by 2.5 min compared to adults in their twenties.[23] The time it takes 70-year-olds to reach baseline light sensitivity is over 10 min longer than for 20-year-olds.[23] Driving at night becomes difficult for seniors because of the need to adjust to oncoming headlights and poorly lit streets and signage. Even in the absence of eye disease, decline in visual functions such as delayed dark adaptation restrict older adults' performance in visual tasks that rely on time-critical decisions such as driving, wayfinding in a dark theater, finding one's way to a toilet, or performing work-related tasks.

Cataracts are a leading cause of vision impairment among seniors. In 2003, 20% of Canadians had cataracts.[18] Individuals with cataracts are sensitive to glare, have blurred vision, and difficulty reading in dim light. There is also reduced depth perception at edges of stairs and curbs. Cataract is typically corrected with surgery but can result in loss of vision if left untreated.

A second major cause of vision decline in older adults is macular degeneration, which affects central vision and occurs in 13%–16% of Canadians.[24] Glaucoma affects nearly 7% of Canadians[24] and results in progressive peripheral field loss, reduced contrast sensitivity, and poor night vision.[20] Macular degeneration results in a loss of ability to distinguish facial features, colors, and reduced depth perception. Some seniors have a combination of both.

For age-related changes in vision, design the following considerations:

- Increase size of print including pictures and signage.
- Locate signage at eye level, which may be lower for older adults who use mobility devices such as canes, walkers, or wheelchairs.
- Increase contrast of print; black print on white background is best for most people. In a dimly lit room, white on black is better. However, for people with cataracts, it is necessary to reduce the amount of scatter light surrounding the task, i.e., white letters on black background is easier to read.[20]
- Increase luminance contrast, for example, between floors and walls, door frames and walls, or toilet seat and toilet, can help people with blurry vision to orient themselves in space. Limit the contrast to relevant objects or environmental cues as too many contrasts can make cues difficult to interpret.
- Use color to differentiate between tasks, particularly when luminance contrast is low. Use colors such as orange or red.
- Illuminance preferences differ widely between young and older adults. In fact, older adults prefer lower lighting than younger adults, possibly because of the amount of scattered light produced in the older eyes.[20,25] Therefore, provide options of levels of lighting for older adults to choose from.
- Prevent glare on flooring and other surfaces by choosing material that is not glossy. If carpeting makes mobility difficult, nonglare flooring, such as Marmoleum, other types of nonslip flooring, and tiles are available in the market. Indirect lighting reduces glare. Window coverings can be used to reduce or eliminate glare during part of the day.
- Keep flooring simple; complex patterns (Figure 4.4) can be misinterpreted as "holes" by people with partial vision.

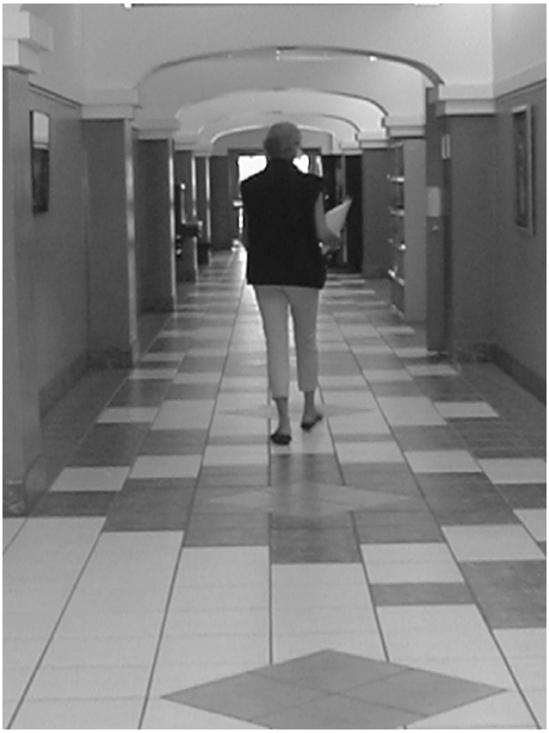

**FIGURE 4.4** Complex floor patterns can confuse older adults with low vision. (Photo taken by Liu, L., 2005.)

- Avoid "dangerous edges" (Figure 4.5a) by using high contrast between wall and flooring (Figure 4.5b). Complex visual cues on stairs can be confusing (Figure 4.6a), keep cues simple by contrasting the tread from the riser and nosing of each step (Figure 4.6b).

### 4.5.2.2 Hearing, Taste, Smell, and Touch

Approximately one-third of older adults between 65 and 74 years, and 50% of those between 75 and 79 years experience hearing loss.[26] Hearing loss can be conductive, sensorineural, or mixed type. Causes of hearing loss include noise exposure, tumors, and diseases. The most common type of hearing loss is "presbycusis," which refers to "sensorineural hearing loss that is associated with aging"[26] (p. 1315). An older adult tends to have difficulty discerning high-frequency sounds such as higher-pitched voices of women or children. Older adults can have difficulty understanding speech when conversing in a crowd or when there is background noise.

Our sense of smell and fine taste begins to decline in the sixth decade.[26] Olfactory function declines by 40% with aging[27] and can affect one's ability to detect unpleasant odors. By age 50 years, adults can lose up to 50% of their taste buds at the front of the tongue.[27] As sweet and salty taste buds atrophy first, older adults may

(a) (b)

**FIGURE 4.5** (a) Dangerous edge. (Photo taken by Liu, L., 2002.) (b) High contrast between wall and floor facilitates wayfinding for people with low vision, or for cognitively impaired older adults. (Photo taken by Liu, L., 2004.)

(a) (b)

**FIGURE 4.6** View from top of stairs: (a) complex visual cues. (Photo taken by Liu, L., 2003); and (b) simple, effective visual cues. (Photo taken by Wickman, R., 2006.)

think that their food taste bitter or sour. These sensory changes frequently result in lowered appetites and a declined interest in meals.

Touch sensitivity varies widely among older adults, but touch thresholds among older adults have been shown to be significantly higher than in younger adults.[28] Thermal sensitivity in the extremities declines with age, particularly in the foot.[29]

Designing considerations for age-related changes in hearing, taste, smell, and touch:

- Approach all older clients with the assumption that there is some degree of hearing loss. This prepares the professional to use approaches that help ensure a client fully participates in the communication process.

- The environment for interview and intervention should facilitate communication through senses other than hearing, such as vision and touch. Communication should occur with eye contact, with minimal or no competing background noise.
- Auditory signals from telephone and smoke detector may not be detectable by older adults who are hard of hearing. Redundancies such as a visual signal can be installed. Remote monitoring of frail older adults living alone is a possibility. This can be done through the use of webcams, provided issues of privacy and security are carefully addressed.
- Demonstrate to clients and family caregivers strategies to deal with declining smell. For example, refrigerated foods can be labeled with an expiry date so that older adults do not have to rely on smell to detect when food is no longer fit for eating. Seniors may not detect leaking gas through smell, therefore, an auditory gas detector can be installed in homes. As taste is affected by aging, older adults who cook for others can rely on measuring utensils and avoid cooking to their taste.
- A decrease in tactile sensitivity stimuli can mean that older clients apply firmer pressure on buttons that operate devices. They are adversely affected by thermal extremes; therefore, provide living spaces where they can control the thermostat or room temperature.

### 4.5.3 Cognitive Changes

Longitudinal studies show that in normal aging, crystallized intelligence, or cumulative information and knowledge, can increase up to the seventh decade and may not decrease until late old age.[30] However, cognitive speed and memory show a linear decline from early adulthood and the decline may accelerate in late old age.[30] Evidence suggests that cognitive speed can decline by 20% at age 40 years and by 40%–60% at age 80 years.[30] With respect to memory, aging is associated with a decline in episodic memory, or memory for events,[31] for example, where we put our keys or parked the car, where we had met someone, and when we had an appointment. Semantic memory associated with highly practiced skills, such as playing the piano and typing, remains constant with aging. However, semantic memory for new information and skills is subjected to age-related declines in performance.[31]

Working memory, or the temporary storage of information, is affected by aging. The multicomponent model of working memory first introduced by Baddeley and Hitch[32] described working memory as consisting of a central executive system, which manipulates information within working memory and controls two storage systems: the phonological loop (auditory information) and the visuospatial scratchpad (visual and spatial information). Recently, based on evidence that not all information can be categorized as auditory or visuospatial alone, a fourth system has been added to the model—the episodic buffer.[33] It is postulated that the episodic buffer holds information from other systems and long-term memory and integrates them into scenes or episodes.[34]

Working memory has been demonstrated to decline with age. For example, in one study, subjects aged 20 to more than 75 years were divided into four groups and given memory updating tasks.[35] The tasks required them to remember the smallest items in each list and to update each piece of information by minimizing irrelevant information or intrusions from items on the previous lists. Researchers reported that the oldest old group, or those older than 75 years, performed worse in memory updating, had the most intrusion errors, and demonstrated the most difficulty with increased task demand.[35] Similar findings have been reported in experimental tasks that simulate everyday activities. In a study that examined age-related cognitive changes, subjects were asked to use a touch screen to follow a series of 14 event-based shopping errand instructions using a virtual street scene on a computer.[36] Older subjects aged 61–80 years and younger university student subjects participated in the study. Researchers concluded that older subjects were less likely than the younger subjects to remember the correct action (e.g., buy a map) associated with a location cue (e.g., Barnes and Noble). Further, older subjects performed significantly worse when they had only one trial, as opposed to three trials, to learn the association between the cue and action.[36]

Design considerations for age-related changes in memory:

- Create environments that are familiar to older adults. This is particularly important in a residential care facility that targets residents from a specific culture, such as Chinese elders, or a specific cohort, such as veterans. Familiarity facilitates a sense of "homelikeness" and allows learning through integration of new information with long-term memory.
- Instructions for therapeutic intervention or operation of equipment and devices should be restricted to a minimal number of steps. If learning of more complex steps is involved, adequate time, education, and follow-up should be designed into the training process.
- Redundant cues, e.g., visual and auditory, would facilitate registration of information. For example, when giving verbal instructions, also provide visual demonstration or illustration. Therapeutic tasks should be meaningful to older users to draw on semantic memory.

## 4.6 AGING AND UNIVERSAL DESIGN

Rehabilitation professionals have an understanding of the aging process and ergonomics. They strive to enable older adults to function and remain within their homes or chosen environments. Rehabilitation professionals are often the first service providers to encounter a need for a home or workplace to be adapted for a client who has experienced a temporary, chronic, or permanent disability. In this way, rehabilitation professionals are consultants to the process of environmental, product, or task modification for a client. As the aging demographic continues to grow, more of the "young-old," or the preretirement cohort, are planning for their future. When there is an opportunity for home renovation or for building a new home, some individuals seek advice on how to "age-proof" or "future-proof" their homes. Rehabilitation professionals who provide consultations in these situations take on a proactive role that will benefit current and future generations. The concept of universal design focuses on the creation of environments and products that meet the needs of older adults. This is a different perspective from the traditional rehabilitation approach of improving an individual's function so that the individual may adapt to the environment.

While the concept of universal design is too broad of a concept for some, and may not seem possible to mandate or legislate, the concept of "visitability" is practical. Visitability can be viewed as a subset of universal design. Visitability is a movement begun by Eleanor Smith of Concrete Change[37] to "change construction practices so that virtually all new homes—not merely those custom-built for occupants who currently have disabilities—offer a few specific features that make the home easier for people who develop a mobility impairment to live in and visit." A visitable home must possess at least the following three features:

- Wide passage doors
- At least a half bath/powder room on the main floor
- At least one zero-step entrance approached by an accessible route on a firm surface no steeper than 1:12, proceeding from a driveway or public sidewalk (Figure 4.7)

Bolingbrook, Illinois passed legislation in 2004 for all homebuilders and developers to adhere to a "Visitability Ordinance." An updated list of visitability initiatives across the United States is available at the Centre for Inclusive Design and Environment's Web site.[38] In Canada, a visitability initiative has begun under the leadership of Laurie Ringaert and in partnership with the Canadian Centre on Disability Studies. More information can be found on their Web site.[39]

Accessibility as a movement was precursor to the current trend of designing for aging. The Americans with Disability Act (ADA) of 1990[40,41] has been the driving force behind barrier-free design in the United States. The Act specifies that

**FIGURE 4.7** Front entrance of home of Ron Wickman, architect. The entrance was created to make R. Wickman's home visitable for his father, Percy Wickman, who used a wheelchair. Percy Wickman served as a politician and was an advocate for persons with disabilities. (Photo taken by Wickman, R., 2006.)

persons with disabilities cannot be discriminated against with respect to employment, transportation, public accommodations, and telecommunications. Although Canada does not have legislation like the ADA, standards do exist for accessible design. For example, the Canadian Standards Association (CSA) International has several National Standard of Canada reports including Accessible Design for the Built Environment,[42] which describes how to make buildings accessible for people with physical or sensory disabilities; and barrier-free design for automated banking machines (ATM),[43] which describes requirements for designing and manufacturing accessible wall-mounted and stand alone, but excluding drive through, ATMs.

More recently, aging is becoming a driving force behind universal or inclusive design. Inclusion of older people and people with disabilities in the mainstream of design does not guarantee the design to be usable by all individuals.[44] However, consideration of design needs from the perspective of older adults can help ensure that a designer considers multiple disabilities (physical, sensory, and cognitive) that challenge older adults. The CSA standards for Inclusive Design for an Aging Population[45] provide core principles, guiding concepts and tools for the design, and provision of products, services, and environments for seniors and those with age-related disabilities. It is important to note that in these guidelines, design of services is included with the design of products and environments. This is in recognition of the importance of good service to address needs that cannot be addressed through good physical design, as well, user satisfaction of a product or environment depends on the associated service and support.

As the proportion of seniors increases globally, the trend is to go beyond designing for people with disabilities or age-related ailments, and to adopt a more inclusive attitude, with attention to esthetics as well as aging-in-place. "Universal design is the design of products, buildings, and exterior spaces to be usable by all people to the greatest extent possible without the need for adaptation or specialized design."[46,47] Proponents of universal design do not negate the need for customized and accessible design altogether. Instead, they are striving to remove boundaries between designs for mainstream and designs for some special populations. For example, environmental control units were originally designed as assistive devices for people with disabilities. Now, variations of these, such as the television remote control, are used by everyone. Indeed, the concept of "smart houses" relies on electronic control of the living environment, remotely or preprogrammed to meet the needs of the resident. When a product or environment benefits the mainstream population, there is a reduction in stigma faced by people regardless of their disability or age. As well, it accommodates people who are "temporarily" handicapped.

The seven principles of universal design were created by a group of 10 experts in 1997 at the Centre for Universal Design, North Carolina State University.[48] Each principle is accompanied by four or five guidelines. The principles are

1. *Equitable use*: The design is useful and marketable to people with diverse abilities.
2. *Flexibility in use*: The design accommodates a wide range of individual preferences and abilities.

3. *Simple and intuitive use*: Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
4. *Perceptible information*: The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
5. *Tolerance for error*: The design minimizes hazards and the adverse consequences of accidental or unintended actions.
6. *Low physical effort*: The design can be used efficiently and comfortably, and with a minimum of fatigue.
7. *Size and space for approach and use*: Appropriate size and space is provided for approach, reach, manipulation, and use, regardless of the user's body size, posture, or mobility.

Table 4.1 provides a Product Evaluation Countdown (CUD, 2002), a scale that can be used by consumers to evaluate the usability of a product.[49] A survey of items related to the principles of universal design has been developed by Story and colleagues[50,51] and tested in a controlled usability tests of products.[52]

## 4.7 DESIGN FOR AGING—STUDENTS IN REHABILITATION LEARN A RELEVANT ROLE

Aging populations can benefit from designs that accommodate a wide range of functional needs, yet are esthetically acceptable and not stigmatizing. One strategy is to provide learning content on assistive technology and devices in the context of universal design. Another strategy is to promote interdisciplinary collaboration between students in rehabilitation and students in design. Some examples of the outcomes of such collaboration are now presented. One purpose is to provide the reader with illustrations of how ergonomics and human factor can be applied to the design of products that enable daily function in older adults, yet the products are inclusive, not segregating. Another purpose is to highlight the benefits of interdisciplinary collaboration between rehabilitation professionals and designers. Of course, successful design must also be informed by the users—older adults themselves.

Since 1997, the Faculty of Rehabilitation Medicine and the Faculty of Arts have collaborated in providing students with opportunities to apply universal design principles to product designs for seniors.* Students in Rehabilitation Medicine† and Industrial Design are familiarized with the following concepts:

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* Rehabilitation course instructor: Lili Liu; industrial design course instructors: Peter Galonski (from 1997 to 1999) and Robert Lederer (from 1999 to present).

† Rehabilitation medicine students were in either the fourth year of the BSc occupational therapy, or the third year of the BSc physical therapy program.

**TABLE 4.1**
**Universal Design: Product Evaluation Countdown**

Have you ever regretted buying a product because it turned out to be difficult to use? Maybe the package was hard for you to open, the instructions were hard to understand, or the controls were hard to operate.

Each of us is unique in our abilities to think, see, hear, handle things, and move around. Products that are easy to use for one person may not be easy for another, whether because of the user's personal abilities or their environment. Everyone has different personal preferences too.

Each of us must consider our own abilities and preferences, and sometimes also the abilities and preferences of other people in our household, when we select products.

*Universal design is an approach to make products and environments as usable as possible for people of all ages and abilities.*

The checklist on the following pages is based on the seven Principles of Universal Design. This list can help you think about your own needs and those of other potential users when selecting products.

When you use this checklist to count down your evaluation of a product, you will agree with some statements more than others. The more statements you agree with, the more likely it is that the product will be easy to use, for you and the other people who might use it—and the less likely you will regret buying it.

This work was supported by a grant from the National Institute on Disability and Rehabilitation Research, U.S. Dept. of Education. The opinions contained in this publication are those of the grantee and do not necessarily reflect those of the sponsor.



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**PRINCIPLE 7. Size and Space for Approach and Use**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7A. | It's easy for me to see all the important elements of this product from any position (such as standing or seated). *Comments:* | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| 7B. | It's easy for me to reach all the important elements of this product from any position (such as standing or seated). *Comments:* | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 7C. | This product fits my hand size. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 7D. | There is enough space for me to use this product with the devices or assistance that I need. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| **PRINCIPLE 6.** | **Low Physical Effort** | | | | | | |
| 6A. | I can use this product comfortably—without awkward movements or uncomfortable postures. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 6B. | I can use this product without overexerting myself. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 6C. | I can use this product without having to repeat any motion enough to cause fatigue or pain. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 6D. | I don’t have to rest after using this product. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| **PRINCIPLE 5.** | **Tolerance for Error** | | | | | | |
| 5A. | The product features I use most are the easiest to reach. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 5B. | This product protects me from potential hazards. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 5C. | If I make a mistake, it won’t cause damage or hurt me. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 5D. | This product forces me to pay attention during critical tasks. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |

(*continued*)

**TABLE 4.1 (continued)**
**Universal Design: Product Evaluation Countdown**

### PRINCIPLE 4. Perceptible Information

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4A. | I can use this product without hearing. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 4B. | I can use this product without vision. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 4C. | I can easily identify the features of this product in order to use instruction manuals or telephone help lines. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 4D. | I can use this product with the aids, devices, or techniques that I use. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |

### PRINCIPLE 3. Simple and Intuitive Use

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 3A. | This product is as simple and straightforward as it can be. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 3B. | This product works just like I expect it to work. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 3C. | I understand the language used in this product. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 3D. | The most important features of this product are the most obvious. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 3E. | This product lets me know that I'm using it the right way. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |

## PRINCIPLE 2. Flexibility in Use

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 2A. | I can use this product in whatever way is effective for me. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 2B. | I can use this product with either my right or left side (hand or foot) alone. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 2C. | I can use this product precisely and accurately. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 2D. | I can use this product at whatever pace I want (quickly or slowly). | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |

## PRINCIPLE 1. Equitable Use

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1A. | This product is as usable for me as it is for anyone else. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 1B. | Using this product doesn't make me feel segregated or stigmatized. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 1C. | This product gives me needed privacy, security, and safety. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |
| 1D. | The design of this product appeals to me. | Not Important | Strongly Disagree | Disagree | Neutral | Agree | Strongly Agree |
| | *Comments:* | | | | | | |



*Source:* CUD, *Universal Design: Product Evaluation Countdown*, Centre for Universal Design, NCSU, 2002. With permission.

- *Partnerships and team work*
  - Students learn about each discipline's areas of expertise, develop group norms, and establish team expectations. Students learn about patents and intellectual property.
- *Research*
  - Market—demographics, functional needs of older people, who is the buyer and who is the end user, pros and cons of existing products, history of the product and future trends, levels of consumer awareness. Development of a persona (case study) helps teams focus on their goals.
  - Function—what does the product do, how is it used, what are the mechanisms, how many tasks must it be capable of, will it do these with the least aggravation to the user, adaptability or additions. Students begin to apply principles of universal design.
  - Ergonomics—activity analysis, what are the user-interface concerns, how is the product handled and used, how does the individual directly engage with it, how easy is it to use, what are the safety concerns, and willingness of user to use it. Students often engage older adults at this stage, if not earlier, to validate their ideas.
  - Engineering—structure considerations, material choices, manufacturing options, recycling issues, mechanics, standards, codes.
  - Economics—do the numbers of users warrant mass production versus batch production, long-term production investment or short-term investment, affordability, stages in production, or a range of products.
  - Ideation—act of generating an innovative approach to address and solve the problem or need. Through brainstorming, lateral thinking, and thinking out of the box, the rehabilitation students and industrial design students bring as many options and ideas as possible to address the components of the design problem. To avoid committing to a quick solution, design teams will consider a broad range of options as they fill the idea funnel (create as many options as possible, eliminate options and develop ideas, and refine and select options). Considerations during ideation state include: form follows function, form follows content, product identity, symbolism, communication, visual language, cultural issues, trends, retro, materials, color, perception. The presentation to the client is in the form of sketches or quick form studies. From this presentation, choices, selections, and composites are made, which are then developed and put back into the design funnel.
  - Concept development—Still a number of options are on the table, and teams go through eliminations. Evaluations during the concept development stage include
    - Functional concerns (will it do what is expected).
    - Scale, proportion, composition (do these work).
    - Perception (does its appearance reflect its value or added value or what it does, is it appropriate).
    - Does the form show the user how it works or its orientation.
    - Two or three renderings or accurate models of the concept are presented. Selections are made and the project moves into further design refinement and drawings for mold making. Technical problems are addressed.

- Teams may stop at this stage to make an actual full-scale model or prototype to test the product.
- Students verify they have addressed the relevant principles of universal design. Students also verify they have addressed relevant human factors and ergonomics of the targeted users. These factors include cognitive abilities (memory, speed of processing), perceptual abilities (vision, hearing, touch), physical abilities (strength, endurance, balance, coordination), and behavior (wandering, social interaction).

The following student designs illustrate how aging and ergonomics are considered in the context of universal design. The high success rate of this collaborative initiative, as demonstrated by the number of award-winning designs, highlights the importance of interdisciplinary collaboration.

### 4.7.1 Example 1

The Tee Planter (Figure 4.8a) was designed by industrial design students Darren Tonn and Reza Bacchus, and rehabilitation students Paul Laliberte and D'Arcy Gainor. It received a Bronze Medal in the 2000 American Society on Aging Universal Design Competition.

This universal design is appealing to golfers of all ages. The students used a persona of a 68-year-old male who had osteoarthritis, a right hip replacement, and chronic low back pain. The objective was to create a design that would eliminate repetitive bending and squatting (Figure 4.8b) so that individuals can play an entire game of golf without having to bend over. Such a device would be useful for individuals with restricted range of motion in the hip, knee, and ankle joints, lower extremity amputees, paraplegics, individuals who need to conserve energy, hypertension, balance deficits, arthritis, or golfers who love gadgets.

An elbow-shaped device is placed at the end of a golf club (Figure 4.8c). When a golf and tee are placed inside the device, high-density foam keeps them in place (Figure 4.8d through f). When pressure is applied on the ball and tee as it is being planted into the ground, a space is created between the foam and the ball (Figure 4.8g), allowing the device to be removed leaving the ball and tee in place (Figure 4.8h). The device can be used to scoop the ball out of the hole (Figure 4.8i), it can also be pulled off the end of the club so it could be fitted onto the end of any club handle, or it can be clipped to the belt or bag, making it versatile and portable.

The simple solution has no moving parts. Its organic shape imitates the hand motion of planting the ball and tee into the ground. It does not stigmatize and could be used by all golfers to consistently plant the tee and ball.

### 4.7.2 Example 2

The Aurora Universal Iron was designed by industrial design students Heather Eadie and Helen Gregson, and rehabilitation students Jocelyn Cromwell and Cindy Holmes. The students wanted to address the common conditions in older populations: reduced vision, decreased stamina, decreased strength, arthritis, weakness due to stroke, and paralysis, as well as other chronic conditions such as multiple sclerosis. The design of most irons do not take into consideration these obstacles faced by

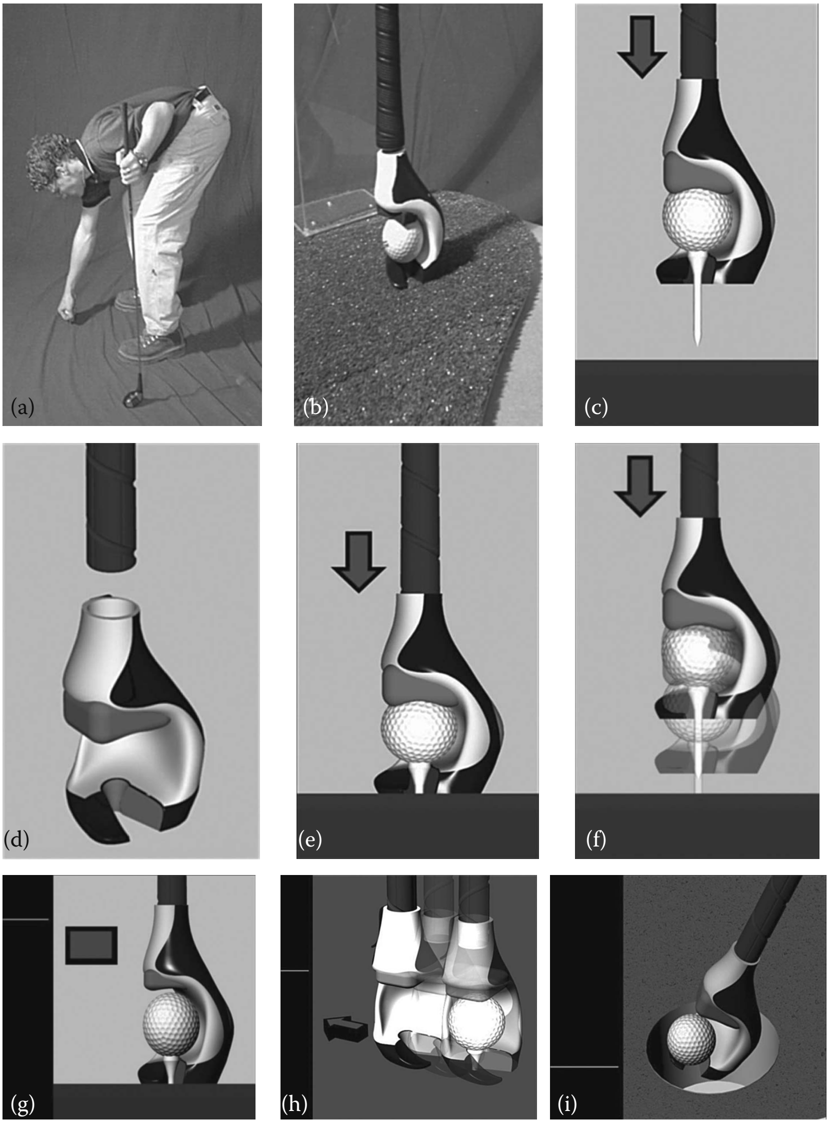


**FIGURE 4.8** (a–i) The "Tee Planter." (Photos and images by Darren Tonn, Reza Bacchus, Paul Laliberte, and D'Arcy Gainor, 1999.)

older adults. Iron handles are not ergonomically designed and cause improper positioning of wrist and hand (Figure 4.9a). Dials and controls are difficult to read and use (Figure 4.9b). Cords can be difficult to manage.

The shape and position of the handle are redesigned. Two handles allow for several possible hand positions depending on user needs and increases the number of people who can use the iron (Figure 4.9c and d). The cylindrical handle is angled at 60° to encourage correct positioning of the wrist. The handle tapers

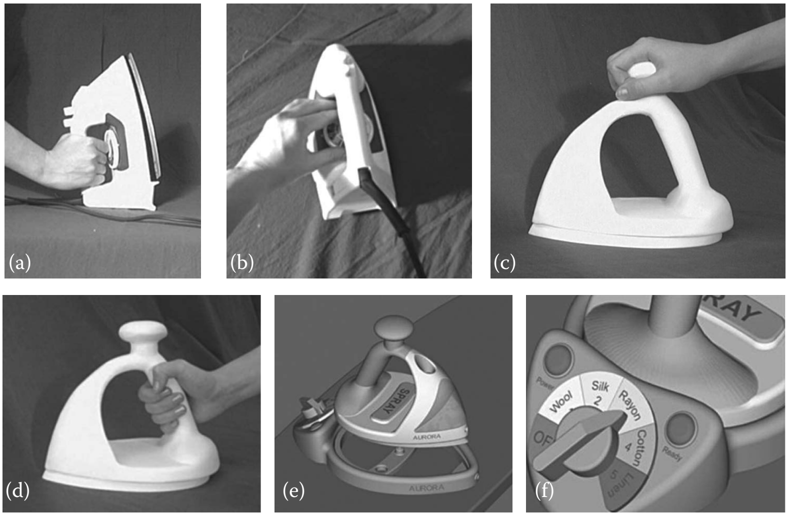


**FIGURE 4.9** (a–f) The "Aurora." (Photos and images by Heather Eadie, Helen Gregson, Jocelyn Cromwell, and Cindy Holmes, 1999.)

from 3.5 cm diameter at the top to 3 cm diameter at the bottom. This allows for a comfortable hand position for any size of hand and creates a power grip, thereby increasing control of the iron. There is ample space around the handle to accommodate larger hands and knuckles. The round, knob-type handle at the top of the iron is 6 cm in diameter and fits comfortably in the palm of most hands. This handle can be used by people with decreased dexterity and poor mobility of the hand. Both handles provide comfortable hand positioning while the user is sitting or standing. The handles have comfortable rubber foam grips to provide tactile input and to facilitate control.

The Aurora is cordless (Figure 4.9e). The iron has a lighter weight than existing designs because the mechanics are located in the charger unit. It allows greater freedom of movement because there is no cord to get in the way. Larger, easier to use controls are located on the charger unit rather than on the iron itself. The large temperature controls are easy to read and dials or buttons click into place (Figure 4.9f). The need to lift the iron and rest it on its end is eliminated. The soleplate is Teflon-coated to ease gliding. The teardrop shape allows for greater efficiency of movement because it has no straight edges and can be moved in any direction. The clear water tank, with large opening, is easy to fill. Safety features include a bumper around the soleplate, automatic shutoff, and easy cord management.

Ideally, the Aurora would be used as part of an improved system of ironing. The act of ironing itself can be quite tiring as it involves standing for a prolonged period of time and a lot of bending and twisting to move garments. The ironing board and seat should be adjustable. An attached clothing basket and hanging rack should be used to minimize energy expenditure through reduced movement. Rounded, wider boards provide more work area within easy reach. Clothing is also less prone to fall off a wider board.

### 4.7.3 Example 3

The Real Chair (Figure 4.10a) was designed by industrial design students Trish Bell and Chet Domanski, and rehabilitation students Jen Dong and Donna Scovil. It received a Silver Medal in the 2000 American Society on Aging Universal Design Competition. The purpose of the design was to address the issue of "geri-chairs" used in nursing homes with residents. Current chairs are institutional in appearance, large, and can be heavy, making residents dependent on help from staff. The students wanted to present a rolling seat that was more esthetically acceptable. Staff can assist a resident to sit or transfer into the chair, then roll the resident comfortably to the edge of the table. When a resident has completed his or her meal, the resident can push away from the table instead of waiting for assistance from staff. A braking mechanism is activated when pressure is placed on the armrest, thereby allowing the user to safely stand up or transfer to a wheelchair (Figure 4.10b).

Specifications include lumbar support 8 in. above the seat. Padding toward the front of the armrest indicate where to place hands when standing or sitting. Polyurethane castors can be used on both linoleum and carpet and do not mark surfaces. Crypton fabric is suggested as it is resistant to spills, stains, and bacteria.

### 4.7.4 Example 4

The Simplicity Range was designed by industrial design students Cam Frith and Zsolt Kovacs, and rehabilitation students Sophie Wilderdijk and Mary Ellen Lamont. This design won the Gold Medal in the 2000 American Society on Aging competition. This design addressed the functional limitations experienced by many older adults in performing instrumental activities of daily living such as meal preparation. An analysis of the task of using a conventional showed that users are required to bend down to open the oven door, reach into the oven or move a rack out of the oven, and lift meals from the oven onto the counter. These movements require adequate

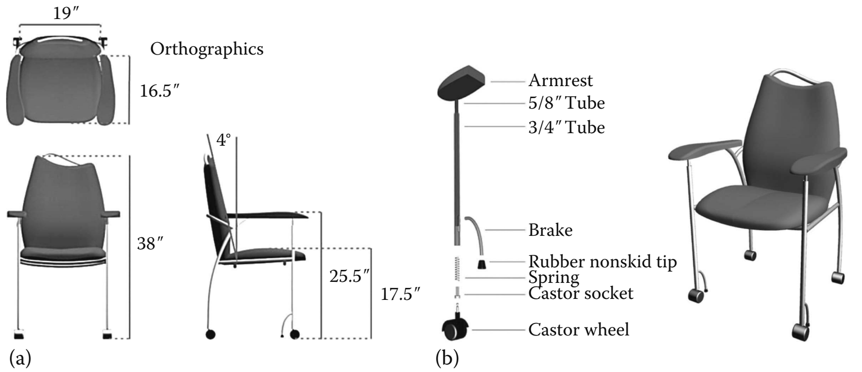


**FIGURE 4.10** (a,b) The "Real Chair." (Images by Trish Bel, Chet Domanski, Jen Dong, and Donna Scovil, 1999.)

range of motion and strength in the upper extremities, back and lower extremities, power grip, visual acuity, depth perception, and good balance. Leg weakness can prevent someone from using proper body mechanics such as bending the knees. Ovens with side-hinged doors do not address the problem of lifting heavy items with arms extended into the hot oven. Bottom-hindged wall ovens require users to lift items from countertop and the door can impede reach into the oven. One German (AEG) design uses a sliding door, but the rack is fixed. Commonly, it is not intuitive for users to know which knobs operate which burners. Digital controls require dexterity and displays may be difficult for older adults to read due to lack of contrast and small print.

The Simplicity Range has the following features that make it ergonomically suitable for the older individual to use. Large control knobs with 180° turning range reduces hand and wrist motion (Figure 4.11a). The high contrast visual scale and incremental steps facilitates accurate and intuitive operation. The oven door pulls straight out, and the rack is affixed to the door rather than the interior of the oven. The oven door can be opened with minimal joint range demands in the hands, wrists, hips, and knees, assisting individuals with osteoporosis, total hip replacement, disk degeneration, and arthritis (Figure 4.11b). The self-raising rack eliminates need for reaching in or lifting the item (Figure 4.11c).

The induction stovetop is common in the market. As a feature of the Simplicity Range, the stovetop can be used to temporarily hold the meal after it comes out of the oven, thereby eliminating the need to life the meal. Advantages of an induction stovetop include easier cleanup of spills, no flames or hot-elements, which can ignite fabric.

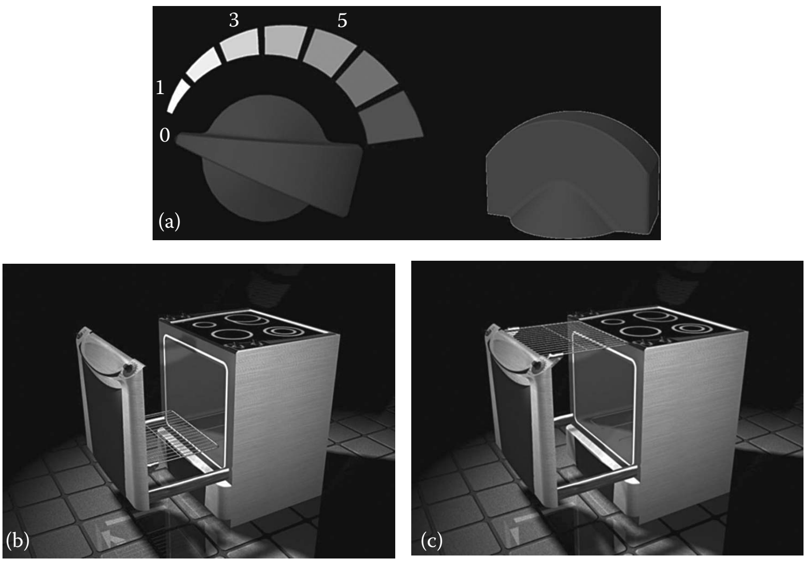


**FIGURE 4.11** (a–c) The "Simplicity Range." (Images by Cam Frith, Zsolt Kovacs, Sophie Wilderdijk, and Mary Ellen Lamont, 1999.)

## 4.8 ROLE OF REHABILITATION IN CONCEPTUALIZATION, DESIGN, CLINICAL TRIAL, USABILITY TESTING, AND COMMERCIALIZATION

"Usability" or "user friendliness" and "ease of use[53]" refer to a set of characteristics of a product or environment from the perspective of users. Usability testing relates to the concept of iterative design where a design in an early stage is presented to users who provide data on aspects of the design that work and other aspects that cause frustration. If warranted, the product is redesigned and retested.[53] Rehabilitation professionals can undertake or participate in usability testing of products by applying their knowledge base of aging, function, and ergonomics. This knowledge should increase the chances that a product meets the needs of older adult users. In environmental design, rehabilitation professionals can provide consultation at the design phase and conduct or participate in postoccupancy evaluations, which will inform future designs. Rehabilitation researchers can apply quantitative and qualitative research approaches that correspond to their research objectives and respondent characteristics.

## 4.9 REHABILITATION AS A LEADER IN DESIGN FOR AGING

Nichols et al.[54] describe a hypothetical case study of a home telemedicine system for older adults to illustrate task analysis and age-related changes that need to be considered in designs for aging. The hypothetical case involved a system that required clients to measure their blood glucose level and then to transmit the data into a computer each evening using USB. This section describes the realization of this hypothetical case study through wireless technology that does not even require home care clients to use a computer.

Telehealth is the delivery of health services at a distance, in real time or asynchronously. These health services include assessments, interventions, follow-up, consultations with specialists, and supervision of support personnel or helping and supporting informal caregivers in the delivery of rehabilitation interventions. Telehealth encompasses telerehabilitation, teledermatology, telepsychiatry, etc. Telehealth may also be used interchangeably with telemedicine. In 2002, Dr. Masako Miyazaki (Figure 4.12), an occupational therapist and researcher at the University of Alberta, conceptualized the application of Bluetooth technology for wireless monitoring of physiological readings of home care clients. The wireless wearable physiological monitor (WWPM) was designed and developed by a team of engineers, computing scientists, health professionals, and other scientists from Canada and Japan. The system is depicted in Figure 4.13. Pulse data are collected continuously by the wearable pulse sensor (WPS) (Figure 4.14a) and the data are picked up by the wireless system (WS) (Figure 4.14b), which are sent to a central server. A glucose meter can be used to collect blood and send glucose level readings to the server via the WS. A client's health professional can use a password to sign onto a Web site to read the client's physiological data. The client and the health professional can use the WS to program regular reminders such as take medications, blood sugar readings, or to call the health professional. Clients can also contact the health professional by pushing the "Call" button.


**FIGURE 4.12** Dr. Masako Miyazaki demonstrates the size of the WPS which is worn on the wrist like a watch, and the WS, which uses Bluetooth to transmit data to a central server. (Photo by Bourque, T., *Edmontonians*, March 2006.)

The features of the watch and WS were originally designed with a focus on elderly clients as the target users. This elderly population would be receiving home care services and be monitored by a health care team for chronic conditions such as diabetes and heart disease. In addition, these individuals would be experiencing common age-related conditions such as functional limitations in vision, hearing, mobility, balance, coordination, and finger dexterity. Therefore, careful consideration of these factors, in addition to the technological requirements of Bluetooth, resulted in the designs depicted in Figure 4.14a and b. Visual displays, labels, and buttons on the WPS are large. Buttons and labels on the WS are readable with good contrast (black on white). An instruction manual used 16 points Arial font, actual photos of the technologies, and training was provided to clients and their informal caregivers.

Once the WWPM system and devices were designed and developed, they were tested in a trial consisting of 98 home care clients with chronic conditions, 25 community-residing frail seniors, and 26 healthy older adults. The trial examined the feasibility, validity, and usability of the WWPM. All older adult participants and

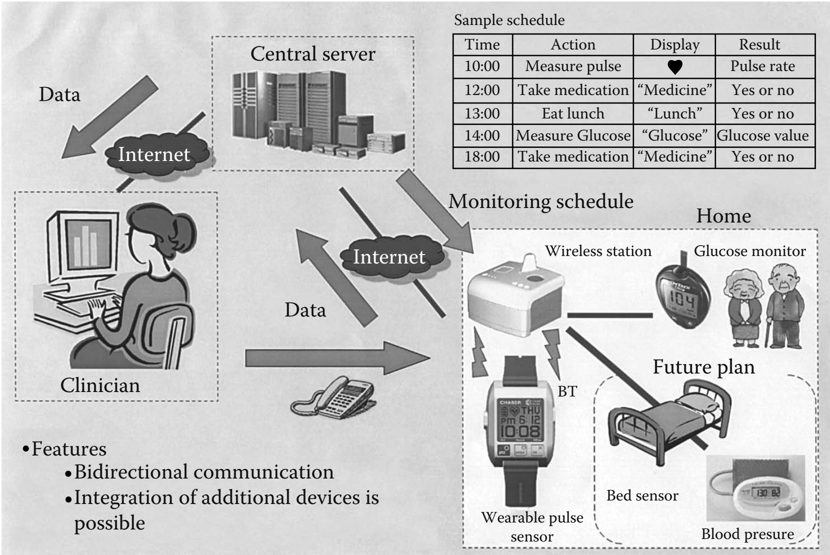


**FIGURE 4.13** Wireless wearable physiological monitor. (Image by Miyazaki, M., 2005.)


(a) (b)

**FIGURE 4.14** (a) WPS. (Image by Miyazaki, M., 2005.) (b) Wireless system. (Photo taken by Miyazaki, M., 2007.)

health professionals involved completed questionnaires or interviews to provide feedback based on their experiences. The data included the usability of the WPS, glucose meter, and the WS from the perspectives of clients and health professionals. The trial proved to be a constructive and valuable phase in the further development of the WWPM. However, as considerations for age-related functional challenges were addressed at the beginning, recommendations for modifications after the trial were not considered to be major. The trial also informed developers and health professionals about strategies for using the WPS with clients who experienced mild cognitive impairment. Despite the clarity of the user-interface, clients with impaired executive function were using the Call buttons when they did not need to call a health professional. In these cases, where a family caregiver was with the client, an effective strategy was to hide the WS under a cloth or cover so that the client could not see the system.

## 4.10 SUMMARY

As older adults form an increasing client base for rehabilitation professionals, the focus of health services need to be directed to the community where older adults prefer to live. In order to enhance their quality of life and promote aging-in-place, more attention needs to be directed to the design of products, environments, and services. Rehabilitation professionals have expertise in ergonomics and human factors as they relate to age-related changes. In collaboration with members of the design disciplines, rehabilitation professionals can make a noticeable impact on older adults as a population.

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