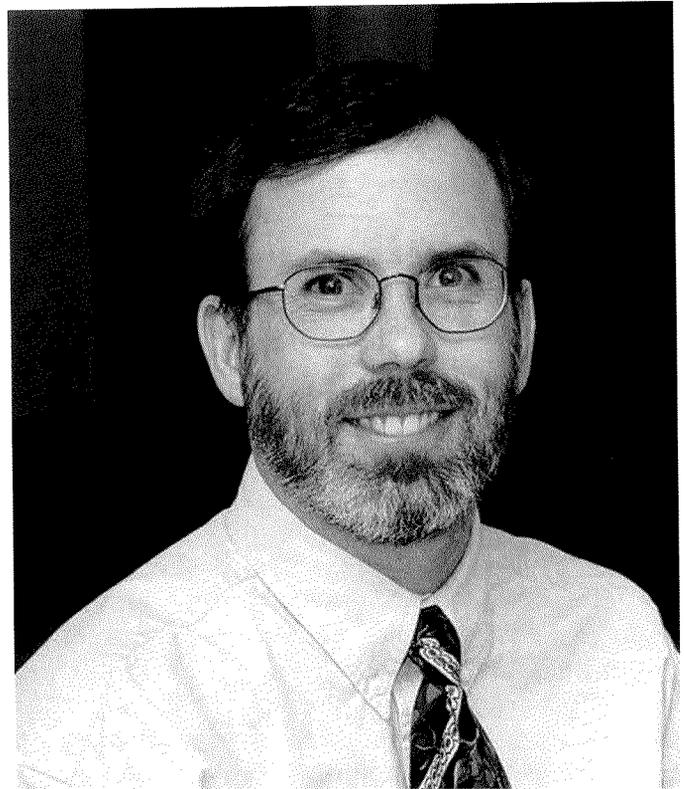


## GUEST EDITORIAL

### Wheelchairs and Related Technology for the Millennium

This is an exciting time to be involved with research and development related to improving the mobility and function of people with physical impairments (1). The recent and impending technological advances promise to change their lives in potentially profound ways: the confluence of technology, biological sciences, and social change have created an environment for progress and growing acceptance of them as persons. It is also noteworthy that they represent a substantial market force: annual expenditures for mobility-related products have reached approximately \$1 billion in the United States alone. The Department of Veterans Affairs spends approximately \$40 million annually on wheelchairs. Because of the market potential and rapid advances in science, notable progress is being made.

We have been developing interface devices for wheelchairs that interact with the user in natural and intuitive ways. An exciting example of this is the pushrim-activated, power-assisted wheelchair (PAPAW), a mobility device that uses the torque applied to the pushrim as the input signal to a control system (2,3), which uses a microcontroller, amplifier, and motor to augment the torque applied by the user. This has the effect of dramatically reducing the amount of effort required for movement and leads to several important implications. Potentially more people can effectively operate a PAPAW and possibly attain the function similar to that of skilled manual wheelchair propulsion, and lower forces needed PAPAW will likely reduce the incidence of repetitive strain injury among wheelchair users (4). As PAPAWs become widely available, clinicians and scientists will be able to determine whether people propel longer distances and enjoy greater involvement in community activities (e.g., strolling in park or shopping in a mall). The lower energy cost of propelling a PAPAW should benefit people with COPD or other physiological limitations. There are also some interesting research questions surrounding motor skills training. Since the degree and form of



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amplification provided by each wheel can be tuned independently, it may be possible to train people with hemiparesis to propel a PAPAW.

We have begun to adapt technologies from mechatronics and robotics to rehabilitation applications, particularly in the area of mobility (3,5). Some exciting applications there are sensor-based control, shared control, human-interactive-control, and learning systems. The

reduced cost and size of sensors has made it possible to design mobility devices that can balance on two wheels and mobility devices that help to detect objects in the environment. Shared control balances the abilities of the user with the capabilities of the mobility device (6). This concept has been embraced in the design of electric-powered wheelchairs, providing clinicians and users the ability to tune the response of the wheelchair to the user's abilities. The PAPA is an example of human-interactive control. Some PAPA control systems seek to simulate the skilled manual wheelchair propulsion performance for all users, regardless of their strength or motor coordination. Human-interactive control is being tested as a means of controlling the wheel clusters for climbing stairs by sensing the change in center-of-mass of the mobility device and user. For example, pushing against the stair railing can cause a change in the device/pilot center-of-gravity, inducing a wheel cluster rotation. Learning systems seek to determine the behavior of the user or the intent of the user and then, based upon past performance, generate control signals. This approach is being introduced into the design of adaptive interfaces that incorporate embedded software. Increasing computational capacity and inexpensive motor control hardware have also made it economically feasible to develop multi-configuration mobility devices, increasing the capacity of the device to operate in a wider variety of environments and modalities, as in accessing high objects, reaching the ground, and traversing unfinished terrain (e.g, sand) (5). Progress is also being made toward electric-powered wheelchairs that allow the user to maneuver inside a van, and to drive the van safely, with minimal modifications to the motor vehicle.

The automobile is such a central aspect of modern living world-wide that the many barriers to the wheelchair user imposed by motor vehicles significantly affect his or her quality of life. Research and development is addressing those barriers in the design of restraint systems, and tie-down mechanisms for wheelchairs within motor vehicles are producing improvements in wheelchairs, motor vehicles, and resulting in international standards (7) that will help wheelchair

users become safe and effective travelers. Restraining both the wheelchair and the user within a motor vehicle presents a formidable challenge: we have recently begun to develop wheelchairs that have their own lap-belt and shoulder restraints. This requires that the wheelchair seating system be strong enough to withstand a vehicle crash and protect the user. Integrated safety restraint systems are also more likely to be used properly when they are more convenient for the user. We understand little about the dynamics and safety of wheelchair users in motor vehicles during rear and side impact collisions, and these types of crashes need to be understood to ensure the safety of wheelchair users and other vehicle passengers. Ideally, the results of this research should be adopted by both wheelchair and motor vehicle original equipment manufacturers. One step in this direction is that some wheelchair manufacturers have begun to incorporate tie-down attachment points within their products, testing them according to existing standards. Transportation standards when using a wheelchair as a seat in a motor vehicle are actively in development with some standards nearly ready for distribution. Future wheelchair and seating standards will likely continue to lead to better products.

Seating and positioning systems have advanced considerably due to research and development. We now have much more information about static seating, and continue to expand that knowledge by looking into the long-term effects of seating and positioning and the proper management of progressive conditions. In order to address spasticity, especially extensor thrusts, work has begun on tunable compliant seating (sometimes called dynamic seating). Tuning the compliance of the seating may allow the wheelchair to respond to the extensor thrust of an individual in a comfortable manner that reduces the frequency of such episodes. The desire to provide greater seating comfort and more functional seating has also led to some intriguing research. Progress made in automotive seating, particularly in adjustment and shock dampening, is making its way into wheelchair seating. The ability of the user to adjust many features of the seat at the touch of a but-

ton may improve the comfort and seating tolerance, increasing his or her capacity for work and social activities. The shocks and vibrations of wheelchair use can cause discomfort and may lead to spinal and pelvic deformities, as well as to some types of pressure sores. Recent research has shown that different cushions have different capacities to dampen these vibrations and shocks (8), and in the increasing number of wheelchairs, especially electric-powered ones, with suspension systems, improved suspension may lead to fewer secondary injuries by reducing exposure to road-loads.

The influence of voluntary wheelchair standards on the quality and cost-effectiveness of wheelchairs has been immeasurable (9). Although the process of achieving consensus on a test method or a level of performance can be lengthy, the results are often most valuable. Another feature of the standards process is continuous quality improvement, resulting in the regular task of updating standards. Currently there are several quite important wheelchair standards in development or on the horizon: these will initially address surface pressure measurement, positioning hardware testing, and seating and positioning nomenclature. It is no surprise that computing advances have also impacted wheelchairs, promising to bring revolutionary new concepts in wheeled mobility. Entirely new control and interface technologies are now possible; therefore, new standards for these innovations are needed and being planned and developed.

While new and improved wheelchair-related technologies are important, equally important is the delivery of assistive technology (AT) services. There are many more people in need of the services of assistive technology specialists than there are regional clinics to serve them. In some cases this has led to the use of satellite clinics or mobile units. The tremendous boom of the internet and the proliferation of communication technology has led to the investigation of telerehabilitation" as a means of expanding the availability of AT expertise (3). While there are many promising technologies and or combinations thereof, I will focus on three that appear in the near term to be effective. The world-wide-

web is being used ever more frequently as a means of exchanging information between clinicians, consumers, and families. Mechanisms such as web-sites, list-serves, network services, and electronic mail have made more information available to all people at an increased rate. Telerehabilitation also encompasses the direct delivery of services via telecommunications technology. Methods are being tried that use direct connections via modem to transmit data, video and voice from a remote clinician (e.g., COTA, PTA) to an expert at a specialized clinic. Issues of training of the clinicians and the quality of the information required are still under investigation. Technologies such as cable-modem and Internet-Two may make it possible for large amounts of data to be transmitted from a user's home to a specialist. An intriguing development that may have tremendous impact on remote and rural AT service delivery is the use of virtualized reality." Virtualized reality is the process of taking digital images (e.g, video or still images) of a real environment (e.g., work or home) and creating a virtual scale model of the environment within a computer. The virtualized environment can be manipulated to demonstrate accessibility modifications or to test drive" assistive devices within the virtualized environment. This can help both employers and consumers make informed decisions about changes in the real environment.

There was a long-held misbelief that wheelchairs and seating systems were simple devices that required little specialized skill to fit or select. The certification and training of rehabilitation engineers (RE) and rehabilitation technologists (RT) is a task that must be approached with both passion and conviction. The Rehabilitation Engineering and Assistive Technology Society of North America (RESNA) has begun the process of developing a credentialing program for RE and RT. This should have a substantial influence on the entire discipline. A sign of a maturing discipline is the emergence of academic departments. Rehabilitation science and technology has reached this important milestone, and now programs must be accredited in order to ensure program and ultimately graduate quality. With credentialed RE and RT as well as accredited

programs, it may be possible for the billing of RE and RT services as well as better service for people with disabilities. Recently work has begun to address the modification of CPT codes to make them more representative of a safe and appropriate assistive technology service delivery process. These changes could eventually lead to a RE and RT services being reimbursed by insurance carriers. This would benefit people with disabilities.

One cannot be involved in rehabilitation without being at least casually aware of the important advances toward improving the restoration of function through molecular and genetic biology (10,11). While it is likely to require considerable time before many forms of physical impairment are affected by advances in restorative research, there are advances that change the practice of rehabilitation on a continuous basis. It is natural to ask the question of how wheelchairs and related technology are being or will be affected by the advances in medicine. Of course there are changes in emergency treatment and rehabilitation. However, there appears to be no less need for AT. This is likely due to the complexity and diversity of disability as well as human life. It is certainly important to continue to keep abreast and implement appropriate medical advances in order to improve the health and well-being of people with disabilities, and AT is an important tool in this process that will advance as part of the global rehabilitation process. The rapid pace of progress in nearly all areas of rehabilitation has created excitement about the field now and for the future.

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