Rehabilitation Engineers, Technologists, and Technicians: Vital Members of the Assistive Technology Team

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Forward

The purpose of this white paper is to describe the rehabilitation engineering professions, specifically rehabilitation engineers, rehabilitation technologists / assistive technologists, and rehabilitation technicians. An ad-hoc committee was convened by the Rehabilitation Engineering and Technologists (RE&T) Professional Standards Group (PSG) at the 2013 annual meeting, RESNA Conference in Seattle, Washington. The ad-hoc committee consists of rehabilitation engineering professionals who have experience working in a variety of environments, and with a multitude of professionals. Since the initiation of the ad-hoc committee, versions of this document were published in the Proceedings of the 2014 RESNA Conference and the 2015 RESNA Conference [1], [2] and feedback has been incorporated into the document from external stakeholders. Furthermore, the white paper was published on the RESNA Website in August of 2015 for public comment. This white paper is the synthesis of the work from the ad-hoc committee, as well as the feedback obtained at the two conference presentations, the public comment period and a review by the RESNA Board of Directors.

The white paper is not meant as a systematic review of the literature, nor a formal research process. However, the literature, including gray literature [3], and expert opinion heavily influenced the development of the white paper.The ad-hoc committee reviewed over 80 different sources in preparing the white paper (see appendix). The white paper defines the role of rehabilitation engineering professionals based on descriptions found in the literature, and historical experience of stakeholders. Furthermore, it describes the role of rehabilitation engineering professionals in numerous work settings, and describes current and future education and training opportunities. Finally, the white paper provides multiple case studies on the role of rehabilitation engineering professionals in a transdisciplinary assistive technology service delivery process.

The white paper is meant as a guide to describe the typical rehabilitation engineering professions in their most generic forms. While there will be exceptions to the rule, the consensus accumulated in this paper and the iterative methods used to aggregate the content, states a majority perspective of current rehabilitation engineering professionals. This document provides a framework for future discussions on the advancement of rehabilitation engineering with the goal of improving the quality of life of individuals with disabilities through the application of science and technology.

Introduction

Rehabilitation Engineering is the application of science and technology to improve the quality of life and increase independence for individuals with disabilities. The rehabilitation engineering profession includes rehabilitation engineers, rehabilitation technologists / assistive technologists, and rehabilitation technicians. This paper assumes that rehabilitation technologist is synonymous with assistive technologist. Rehabilitation engineering professionals primarily work in the fields of assistive technology (i.e. focus on performance of functional activities), rehabilitation technology (i.e. focus on remediation of limitations), and universal design (i.e. focus on access for all people independent of ability) [4]–[7]. As the fields of assistive technology and rehabilitation technology have advanced, so has the field of rehabilitation engineering in providing more educational, social, and vocational opportunities for individuals with disabilities.

Initially, rehabilitation engineering professionals (REP), which in this paper includes engineers, technologists, and technicians, focused on research, design and fabrication of custom devices. As the field has advanced, more devices have become commercially available, and more consumer products have incorporated universal design principles, causing the role of REPs to evolve. REPs now have a greater role in assistive technology and rehabilitation technology, which include the following areas:

- customization and integration of existing assistive technology and rehabilitation technology;
- research, development, design and production of devices;
- analysis of human performance (e.g. application of quantitative tools);
- education and training;
- application of outcome measures throughout the assistive technology service delivery process; and
- project management.

The advancement of the assistive technology and rehabilitation technology fields has led to a change in the practice of rehabilitation engineering. In order to stay current with the changes within the field of practice, it is important to define the rehabilitation engineering profession.

Rehabilitation Engineering Professionals Defined

The simplest and most direct definition for the field of Rehabilitation Engineering is provided by the IEEE Engineering in Medicine and Biology Society. The definition simply states: “Rehabilitation Engineering is the application of science and technology to improve the quality of life for people with disabilities.”[8] Although numerous definitions for rehabilitation engineering have been described in the literature [6], [9]–[12], this definition is eloquent in that it first describes engineering as an activity, and then defines the population for which the activity is applied. This clearly identifies the uniqueness of engineering professionals, as opposed to inventors or scientists. This paper adapts and synthesizes peer-reviewed literature (primary, secondary, and tertiary) and gray literature that defines engineer, technologist and technician to define the Rehabilitation Engineering Professionals [13]–[16].

> **Rehabilitation Engineer (RE)** uses the innovative and methodical application of scientific knowledge and technology to design and develop a device, system or process, which is intended to satisfy the human needs of an individual with a disability.

> **Rehabilitation Technologist / Assistive Technologist (RT/AT)** combines scientific and engineering knowledge and methods with technical skills to complement engineering activities for an individual with a disability.

> **Rehabilitation Technician (RTn)** works with equipment, primarily assembling and testing component parts of devices or systems that have been designed by others for individuals with disabilities; usually under direct supervision of a rehabilitation engineer or rehabilitation technologist / assistive technologist. Their preferences are given to assembly, repair, or evolutionary improvements to technical equipment by learning its characteristics, rather than by studying the scientific or engineering basis for its original design.

Many professionals perform more than one REP role throughout their work. The roles and responsibilities of the RTn are a subset of the RT/AT, which are a subset of the RE. This is best represented by three circles of various sizes. The smallest circle represents the RTn, and is completely encompassed by the medium circle, which represents the RT/AT. Finally, the largest circle encompasses both the small and medium circles, which represents the RE (Figure 1). The nested circles represent the fact that the RT/AT may at times perform the roles of the RTn, and the RE may at times perform the roles of both the RT/AT and RTn. The specific roles and responsibilities of the RTn, RT/AT and RE are often defined by the requirements of the job, and the unique setting.

Although there are similarities across the REPs, which leads to a synergistic collaboration, the environment and job description ultimately define the roles and responsibilities of each REP.

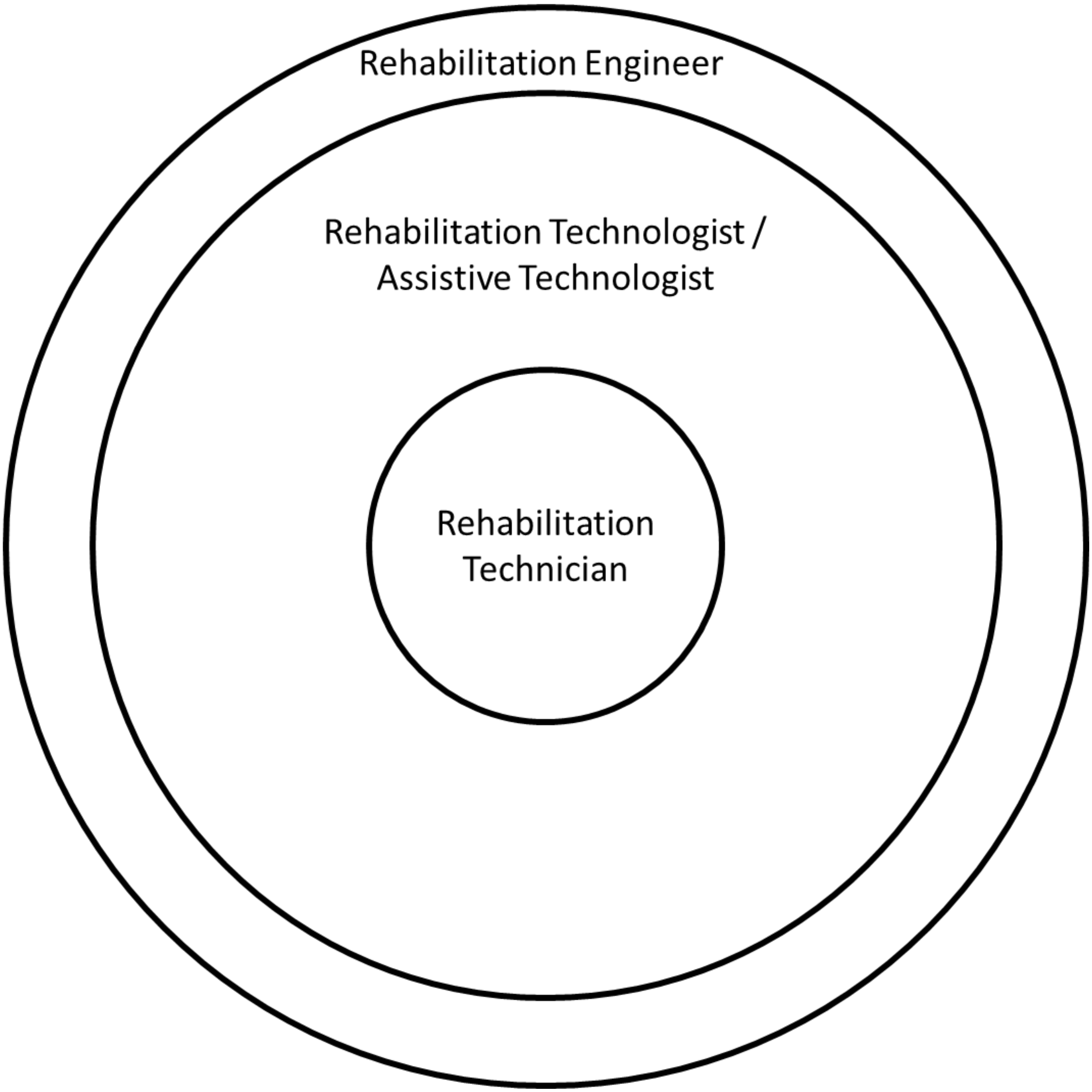

Figure 1. Intersection of the rehabilitation engineering professionals.

Education and Training for Rehabilitation Engineering Professionals

Past

As the field of Rehabilitation Engineering advanced through the late 1970s and 1980s, most notably with the start of the Rehabilitation Engineering Society of North America (RESNA) in 1979, so did opportunities for education and training. A call for education, training, and credentialing in rehabilitation science and engineering was described in 1997 in “Enabling America” [17]. In this book, the authors made four recommendations, one was to increase doctoral and postdoctoral education “...to help encourage the development of the field and respond to the expanding research needs.” Therefore, the education, training, and credentialing opportunities have primarily focused on engineering programs, and rehabilitation science and technology programs. The primary source of federal funding for education and training has come from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) [formerly National Institute on Disability and Rehabilitation Research (NIDRR)], with activities surrounding the Rehabilitation Engineering Research Centers (RERCs) [formerly Rehabilitation Engineering Centers (RECs)], which continues today. In parallel, RESNA has lead the credentialing activities with the development of the Assistive Technology Professional (ATP), the Seating and Mobility Specialist (SMS), and the Rehabilitation Engineering Technologist (RET) certifications.

In 2000, an entire issue of Technology and Disability was devoted to the field of rehabilitation science and the role of graduate education. These articles focused on masters and doctoral level education, as well as opportunities for collaboration between the Schools of Engineering and Health and Rehabilitation Sciences[18], [19]. Though the articles focused on graduate education, their emphasis influences undergraduate education because these programs recruit from undergraduate programs. An increased need for REPs in design, sales, service delivery, and research and development, will only be met through the continued development of vocational, undergraduate and graduate programs in engineering, health and rehabilitation sciences, and special education.

Present

Traditionally, the majority of rehabilitation engineers have a foundational undergraduate or graduate degree in Biomedical Engineering (BME), Computer Engineering (CE), Electrical Engineering (EE), or Mechanical Engineering (ME) (examples shown in Figure 2a). Individuals then specialize in the health and rehabilitation sciences and gain post graduate credentials, such as academic specializations (e.g. minor or certificate programs) and/or certifications (e.g. ATP, SMS, RET). Training includes formal instruction in principles of design, ergonomics, biomechanics, mechanical and electrical systems, material sciences, and life sciences. Students also gain an understanding of the functional capabilities and prognosis of people with disabilities.

A common pathway towards becoming a rehabilitation technologist / assistive technologist is through an associate, undergraduate, or graduate degree in health and rehabilitation sciences (e.g. Occupational Therapy, Physical Therapy, Speech and Language Pathology, Rehabilitation Counseling), engineering technology or special education with a focus on assistive technology (examples of common pathways are illustrated in Figure 2b). The health and rehabilitation sciences or education degrees provide a foundation, then students specialize in technology sciences through post graduate credentials, such as academic specializations (e.g. minor or certificate programs) and/or certifications (e.g. ATP, SMS, RET). Similarly, the technology degree provides a technology foundation and then students acquire knowledge of health and rehabilitation science and assistive technology through post-graduate education.

Finally, the majority of rehabilitation technicians have post-secondary training from a vocational school or community college in computer technology, industrial electronics, machine tool technology, or health science (examples are shown in Figure 2c). The rehabilitation technician usually gains knowledge of working with people with disabilities through internships with rehabilitation facilities, durable medical equipment providers, or vocational rehabilitation agencies. The rehabilitation technician may eventually qualify for the role of the rehabilitation technologist / assistive technologist through several years of apprenticeship as a rehabilitation technician and demonstrated competency via the assistive technology professional (ATP) certification.

As REPs continue to advance the science of rehabilitation engineering, the need for dedicated REP training and credentialing programs will grow through academic, apprenticeship, and professional development programs. Currently, the authors do not know of any dedicated programs in the rehabilitation engineering professions at the undergraduate level. However, the principles of rehabilitation engineering are incorporated in existing engineering, engineering technology, and rehabilitation science programs. These programs are designed to provide the knowledge, skills, and experiences required to pass the RESNA Assistive Technology Professional (ATP) Certification Exam.

Future

Future opportunities exist for training REPs at the associates, bachelors, and masters degree levels. An opportunity exists for developing associates degree programs for rehabilitation technicians and rehabilitation technologists / assistive technologists through existing vocational programs and community colleges. Furthermore, an opportunity exists for developing degree programs for rehabilitation technologists / assistive technologists through existing undergraduate and graduate special education, and health and rehabilitation science programs (e.g. assistive technology concentrations). Finally, opportunities exist for developing bachelors or masters degree programs for rehabilitation engineers through existing engineering programs (e.g. degree in biomedical, computer, electrical, or mechanical engineering with a certificate/minor in rehabilitation engineering). Numerous opportunities for specializing in the rehabilitation engineering professions are currently available within multiple engineering, health and rehabilitation science, and special education programs. In the future, these opportunities may turn into dedicated training programs within the engineering, rehabilitation sciences, and special education curricula.

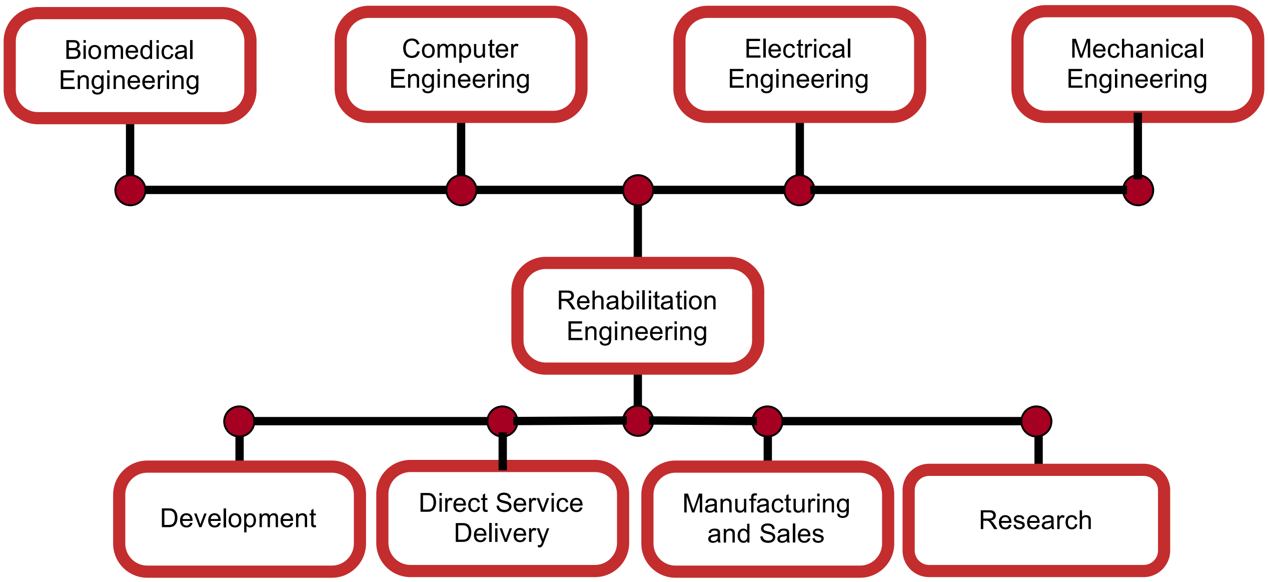

Figure 2a. Examples of engineering educational programs that feed into becoming a rehabilitation engineer, and the associated areas of employment.

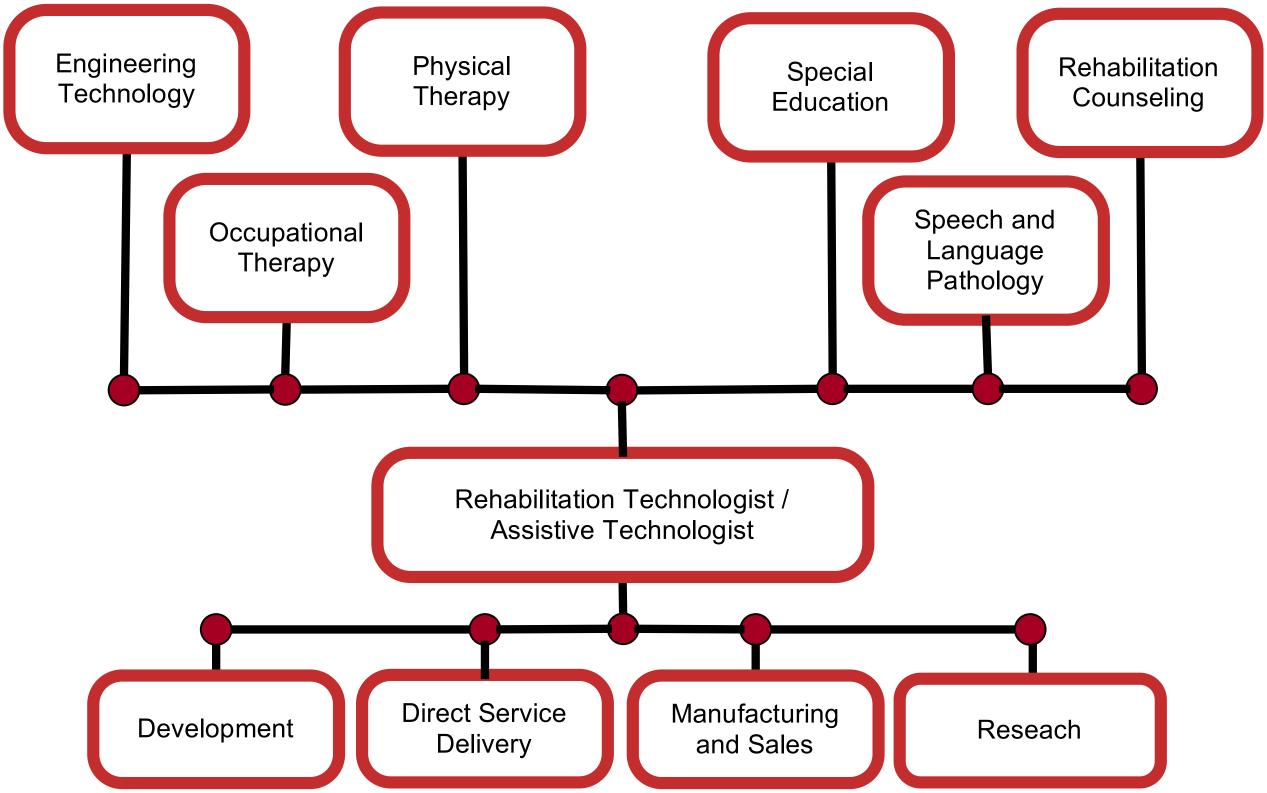

Figure 2b. Examples of educational programs that feed into becoming a rehabilitation technologist / assistive technologist, and the associated areas of employment.

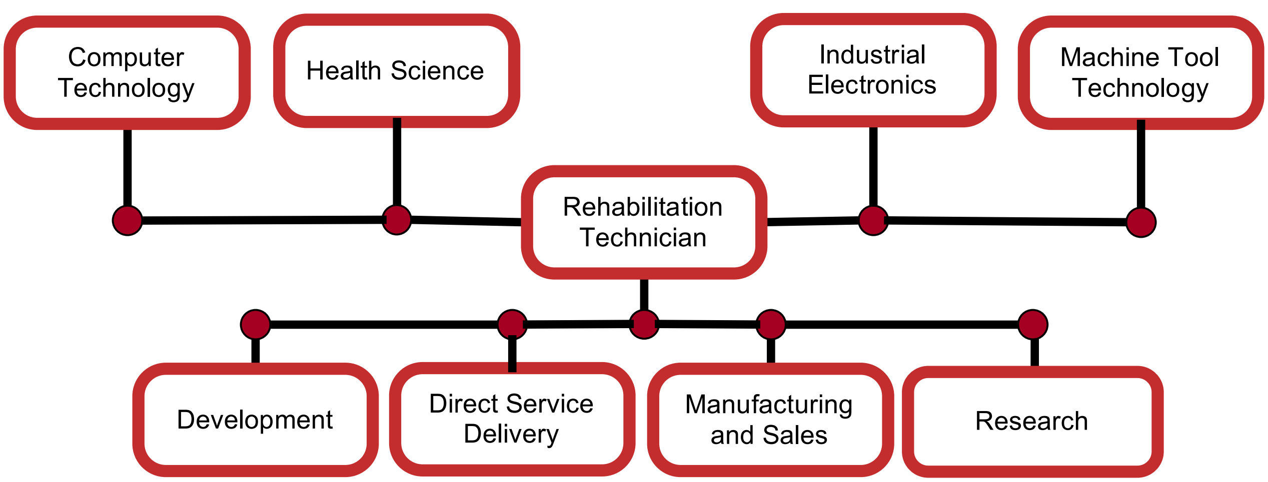

Figure 2c. Examples of educational programs that feed into becoming a rehabilitation technician, and the associated areas of employment.

Employment Opportunities

Rehabilitation engineering professionals typically work in either the indirect consumer service delivery market or the direct consumer service delivery sector. Cook and Polgar describe the connection between the direct and indirect consumer service delivery sectors [4]. There are seven indirect sectors that support the direct sectors: basic research, applied research, product development, manufacturing, product distribution, information and referral, and education and training. Furthermore, Cook and Polgar describe eight potential settings in which the direct consumer delivery process takes place [4], some of which only exist in the United States. There may be similar programs in other countries. These settings include rehabilitation programs, university programs, state agency programs, private practice, rehabilitation technology supplier / durable medical equipment supplier, Department of Veterans Affairs, local affiliate of a national nonprofit disability organization, and volunteer organizations. Each one of these settings provide an opportunity for REP employment. The remainder of this section highlights examples of the employment opportunities within some of these sectors and settings. The descriptions found in the following sectors are not meant to be exhaustive nor do they completely describe the role of the REP.

<u>Indirect consumer service delivery</u>

Basic Research

Engineers, technologists and technicians conduct basic research to improve understanding of the role of disability and technology. For example, the engineer or technologist will develop the foundational content for the research proposal, and lead the research project, while the technician will maintain laboratory equipment and follow research protocols to collect data. Synthesis and communication of the results is a collaborative process of the research team.

Applied Research

Rehabilitation engineers, rehabilitation technologists / assistive technologists, and rehabilitation technicians perform applied research through independent testing laboratories and academic institutions. They typically conduct stress, performance and failure analysis tests to determine the structural integrity of assistive technology (e.g. wheelchairs, wheelchair transportation equipment, and emergency stair travel devices). Rehabilitation engineers apply mathematical models and rigorous experimental methods in developing the tests and analyzing the results. Rehabilitation technologists / assistive technologists and technicians play a critical role in operationalizing the testing procedures and providing feedback during the reporting process.

Rehabilitation engineers work in research and development to design and test new products. Others conduct applied research to solve practical problems for people with disabilities. They test new equipment or software in multiple environments prior to product launch. In this scenario, rehabilitation technologists / assistive technologists and rehabilitation technicians fabricate custom testing equipment and carry out the testing procedures. Synthesis and communication of the results is a collaborative process of the research team.

Product Development

When working in product development, the rehabilitation engineering professional is fabricating a working prototype of an assistive technology device through a systematic iterative design process[13], [20]. The rehabilitation engineer applies design principles and appropriate standards with a focus on injury prevention, universal design, enabling independence, learning, or reducing caregiver burden. The rehabilitation technician fabricates the device for alpha and beta testing. The engineer and technologist bring their clinical knowledge and experience of working with people with disabilities to the design and testing process.

Manufacturing

Rehabilitation engineering professionals working in manufacturing transform working prototypes into mass produced consumer products[13], [20]. The rehabilitation engineer in manufacturing brings the clinical knowledge, skills and experience of working with people with disabilities to the manufacturing process. The rehabilitation technician often is involved in fabrication of the designs provided by the engineers. Rehabilitation engineers develop and monitor testing protocols to ensure the device meets state, federal and international standards. Rehabilitation technicians implement the tests. The engineer analyzes the safety of the product based on the test results.

Product Distribution

Product distribution typically falls in two categories: 1) business to business and 2) direct-to-consumer. In the business to business category, rehabilitation engineers typically function as application engineers by integrating the assistive technology devices their company produces into another manufacturer's device. They support engineers and technologists that integrate their products as a component in a turnkey system. An example of the business to business interaction is the integration of a power wheelchair seating system from one manufacturer into the power wheelchair base of another manufacturer.

In the direct-to-consumer category, rehabilitation engineers and rehabilitation technologists / assistive technologists function as sales associates that support local sales staff and sell directly to the consumer. The direct-to-consumer manufacturers are typically large national companies that have local sales staff, or sell direct via the internet. Examples include (AAC) device manufacturers with local sales staff and computer software/hardware manufacturers with an online store.

Information and Referral

The rehabilitation technologist / assistive technologist typically provides information and referral services to people with disabilities and their families. They provide information about assistive technology devices and services, along with information on local resources and service providers.

Education and Training

The rehabilitation engineering professional will provide formal education and training to professionals in the field through formal educational programs. They will also provide education and training to consumers and caregivers upon delivery and implementation of assistive technology.

The rehabilitation engineer who works in education and training develops curriculum to provide rehabilitation engineering education at a college or university. The rehabilitation technologist / assistive technologist often participates in training professionals in the health sciences and education fields that are specializing in assistive technology. They teach assistive technology courses and certificate programs at many universities, using their knowledge, skills and experience to enhance their instruction.

The rehabilitation technologist / assistive technologist often develops instructional materials for new products and provides commercial product training in a clinical, school, or vocational setting. The training takes place in the different settings and applications that it is intended to be used. It includes the end-user, but when necessary, it also includes their support team.

The rehabilitation technician provides training on the maintenance, care and warranty of devices provided to the person with a disability. This training includes all stakeholders in order to maximize successful implementation of the assistive technology.

Direct Consumer Service Delivery

University Program

The rehabilitation engineering professional in a university program participates in the AT assessment and intervention with the transdisciplinary team (e.g. consumer, educator, family, occupational therapists, physical therapists, speech and language pathologists). The rehabilitation technologist / assistive technologist will often take on the role of project manager to coordinate equipment and technology services for the individual with a disability. The technologist establishes goals with measurable results over specified timelines. This includes trials and training with assistive technology used in educational, employment and community settings. The data collected during trials with equipment is critical in evidence based practice, an increasingly important component of the service delivery process. The engineer directs the custom technology integration, fabrication, and design. The technician prepares, assembles and configures the equipment according to the specifications and recommendations of the transdisciplinary team. Often the rehabilitation engineer or rehabilitation technologist / assistive technologist will take on the role of team lead/manager for the overall management of the assistive technology center.

Rehabilitation Program

In a rehabilitation setting (e.g. inpatient, outpatient, acute care), REPs are involved in increasing patient's access to technology in the room (e.g. call system and phone), integration of therapies, and increasing the patient's independence (e.g. wheelchair, computer, communication equipment). In this model, a rehabilitation technician installs, configures and repairs accessible call systems and equipment. The rehabilitation technologist / assistive technologist would be involved as part of the transdisciplinary team (e.g. family, occupational therapists, patient, physical therapists, physicians, and speech and language pathologists). They develop and integrate solutions to increase the patient's independence. The rehabilitation engineer collects and analyzes performance measures to quantify the effectiveness of the technology during the assessment and implementation phases.

State Agency Programs

State agency programs (e.g. primary education, secondary education, vocational rehabilitation) employ rehabilitation engineering professionals to provide assistive technology services to their consumers/students with disabilities to reach employment or education goals. The REP works with the transdisciplinary team to provide the assistive technology assessment and intervention. The technologist leads the assessment by setting quantifiable goals and timelines. Best practices include conducting trials, collecting data and providing training with assistive technology in the home, work, community, and school environments. The engineer directs the custom technology integration, fabrication and design. The technician prepares and configures the equipment so that it can be implemented to the recommendations provided by the transdisciplinary team.

Assistive Technology Supplier / Durable Medical Equipment Supplier

A REP working for an assistive technology supplier (also known as rehabilitation technology supplier) or durable medical equipment supplier (DMES), will be the direct consumer contact and will collaborate with other rehabilitation professionals (e.g. occupational therapist, physical therapist, speech language pathologist) to provide and support appropriate assistive technology. The rehabilitation engineer is the liaison between the manufacturer(s), clinician and consumer when providing custom applications. The engineer also integrates technologies from multiple manufacturers. The rehabilitation technologist / assistive technologist supports the transdisciplinary team in acquiring and implementing assistive technology. The rehabilitation technician will set-up equipment for evaluations and for fittings, but generally will not interact directly with the consumer.

Department of Veterans Affairs

At the Department of Veterans Affairs, the rehabilitation engineer and technologist typically work for the Rehabilitation Services. The technician typically works for the Prosthetic and Sensory Aids Services. The rehabilitation engineer will assess the Veteran's need for assistive technology in collaboration with the transdisciplinary team. The engineer will also verify the proper implementation of the technology. The technologist will assist with set-up and trial of evaluation equipment. The technician will acquire the recommended equipment, and set-up the equipment in preparation for the implementation and training.

Rehabilitation Engineering Professionals – A Series of Case Studies

The 3 case studies provide an overview of the role of rehabilitation engineering professions in three unique settings: education/vocation, rehabilitation, and home/community. These case studies describe the role of rehabilitation engineering professionals as members of the transdisciplinary team. The case studies demonstrate the overlap across the rehabilitation engineering professions, as described in Figure 1. For example, the RT/AT in Case 1 could have fabricated and assembled the prototype and new device instead of the RTn. The RE in Case 2 could have taken on the role of the manufacturer representative, or an RT/AT or an RTn could have made the special connecting cable. Last, the RT/AT in Case 3 could have taken on the role of the RTn if the RT/AT was skilled in fabrication and welding. Though there is overlap among the rehabilitation engineering professions, which is required for communication among the transdisciplinary team, best practice dictates practicing to an individual's professional strengths and recognizing limitations in terms of a professional's scope of practice. Therefore, there is a need for all three rehabilitation engineering professionals on the assistive technology service delivery team in order to design, fabricate and implement assistive technology devices that improve the quality of life of individuals with disabilities.

Case Study 1

Charlie is a 28-year-old male who experienced a stroke six years ago. The residual impairments from his stroke include hemiplegia to the left side and visual impairments. Charlie is legally blind, has no peripheral vision to his left side, and a limited field of vision to his right side. His acuity is also impaired and he wears corrective lenses, however, he also sometimes needs a magnifying glass to see small print. Charlie's hemiplegia is significant; resulting in extremely limited movement in his left arm. For example, he has difficulty using it to stabilize a piece of paper, but with effort and the assistance of his right arm, he can position his left arm to hold down the paper to sign. He walks with an asymmetric gait, resulting in a slower walking speed. He sometimes falls, but claims this is not related to his asymmetric gait; instead it is due to dizzy spells when he is sick. Charlie also has decreased strength on his right side, but reports no fine motor impairments.

Charlie is attending a local technical college in their Machine Tool Operator program. This is a one-year program that he plans to complete over an extended period. It will result in a technical diploma and provides the opportunity to move forward into the Machine Tooling Technics program. Charlie had assistance in his first semester but wants to increase his independence. His instructors are supportive of the use of assistive technology and trying new approaches.

A referral was made by Charlie's Disability Services Specialist at the college for an assistive technology assessment and it was funded through the Division of Vocational Rehabilitation. A rehabilitation technologist / assistive technologist lead the assistive technology assessment and assembled a transdisciplinary team to include: Charlie, the disability services specialist, Charlie's instructors (who also represented the perspectives of an employer because of their experiences in industry) and a rehabilitation engineer. The goal was to determine what accommodations would be required to allow Charlie to safely and efficiently work as a machinist and to determine if this is a viable career path with his disability. The plan included demonstration of accommodations by Charlie, to show prospective employers his skills and alleviate hiring concerns.

During the assessment, background information was collected and two primary areas of need were identified. First, Charlie's motor and visual impairments made accurate measuring difficult resulting in poor quality work. Second, Charlie was unable to change tools in the CNC mill because it is a two-hand operation. The RT/AT worked with Charlie and the team to address improving measurements. They considered a variety of options and strategies to improve Charlie's ability to both manipulate and read the calipers. With input from his instructors, the team determined that various length digital calipers with memory function would allow Charlie to save measurements after the caliper was removed from the piece. They also determined that Charlie should have a personal set of drill bits to save time and efficiency by avoiding measurement of each bit prior to use.

The RT/AT also led the assessment regarding changing parts on the tools. The operation requires two hands, one to push a button to keep the jaws open and one to position the tool into the chuck. The RT/AT helped to explore several solutions including modifications to the CNC mill, use of a head operated button pusher, a custom jig that functions similar to a pogo stick to position and push the tool into the machine prior to pushing the button, and a foot operated button pusher. The team deliberated all the options and determined the ideal solution was an electro-mechanical button pusher to hold the jaws of the chuck open on the mill, that Charlie would operate with his knee. Electro-mechanical was preferred over a mechanical solution because safety features could be programmed into it. The RT/AT compiled a potential solution with specification list and consulted with the RE to determine the most appropriate design and final plan.

The RE designed the device according the RT/AT's specifications and together they revised the design and presented it to the team for approval and to seek funding.

After funding was approved, the RT/AT facilitated the implementation, the RE finalized the design and worked with the RTn to build the device. The RT/AT and RE worked together with Charlie to test the prototype and make needed modifications The RE worked with the RTn to make modifications, install the device, and train Charlie on use of the device. The RT/AT developed and implemented a quality assurance plan after services were complete. Charlie responded to an anonymous survey regarding the communication, performance and training throughout the process. He identified that he has not had any problems using the technology since it was implemented.

Case Study 2

Joe is a 37-year-old male with a spinal cord injury at the 4th cervical vertebrae. His level of impairment was classified as American Spinal Injury Association (ASIA) C [21]. He has dysarthria, decreased inspiratory/expiratory strength and volume, and no movement below the neck. Joe and his fiancée were seen by a transdisciplinary team of occupational therapist (OT), physical therapist (PT), speech-language pathologist (SLP), rehabilitation engineer (RE), and multiple assistive technology manufacturer representatives. The assistive technology manufacturer representatives are rehabilitation technologists / assistive technologists (RT/AT). Joe received a mobility evaluation by the transdisciplinary team and was issued a front wheel drive power wheelchair (PWC) with multiple seat functions (tilt, recline, stand, seat elevator, leg elevate). The power wheelchair was assembled by a rehabilitation technician (RTn) based on the configuration provided by the physical therapist and rehabilitation engineer during the evaluation. The rehabilitation technologist / assistive technologist, in this case the power wheelchair manufacturer representative, provided detailed product specifications in order to best match the technology to the individual.

Joe was in the beginning stages of an augmentative and alternative communication (AAC) evaluation. The AAC evaluation included the OT, RE, RT/AT, and SLP. The OT addressed access issues while the SLP addressed communication issues. The RE addressed the integration of multiple technologies, most notably the power wheelchair and AAC device. The integration included the fabrication of new devices and modification of existing devices. The RT/AT was the AAC manufacturer representative, and provided detailed product specifications for the AAC devices. Prior to the AAC evaluation, Joe was successfully utilizing a chin control consisting of a swing away micro joystick for drive control of his PWC and an egg switch (i.e. a widely used, oval shaped, easily activated switch) for mode and power functions on his PWC. The RE relied on documentation from the treating clinicians for details about Joe's functional abilities.

Due to Joe's spinal cord injury, he was unable to communicate verbally, which severely decreased his ability to participate in conversations, especially with anyone other than his fiancée. Consequently, independent direction of his care and participation in recreation activities was very difficult. Other activities that were difficult or impossible for Joe to accomplish included independent trips outside of the home, entering/exiting home, watching television, and online communication.

Joe's primary goals were to access the home and community environment, communicate effectively, access a computer independently for email and internet browsing, and access a smartphone for text messaging and telephone calls. The professionals' (RE, OT, and SLP) objectives for this part of the assessment were to select an AAC device and determine an appropriate access method, this process was lead and facilitated by the RE. The team would evaluate potential computer access methods and environmental control systems (aka electronic aids for daily living) in future evaluations.

The primary objective of the RE was to integrate all new equipment with Joe's existing technology. The RE worked with both the PWC RT/AT and the AAC RT/AT to obtain product specification and acquire interface modules for integration of the AAC device with the PWC. The RE also worked with the RTn to set-up and configure the devices during the evaluation and trial periods. The team evaluated 3 AAC devices, with 3 different access methods, and multiple access locations. The 3 AAC devices were dedicated devices with dynamic displays. The access methods included a head mouse with dwell or external switch, USB chin joystick control, and Bluetooth wheelchair chin joystick control.

The most successful access method was chin joystick control with dwell. The RT/AT recommended using the wheelchair's Bluetooth capability for simplicity of integrating with the existing power wheelchair electronics. This gave Joe independent control of the AAC device when it was mounted on the wheelchair. Joe selected the AAC device he preferred, and it was mounted to the wheelchair on an easily removable mount arm allowing for safe and efficient transfers via lift. Also, Joe was concerned with the battery life of the AAC device, so the RE integrated the AAC device's power supply to the wheelchair's 24V power system. Additionally, the RE made a custom cable to interface an input/output module on the wheelchair to the AAC device's switch input configured for on/off control. This gave Joe the ability to turn on and off his device independently, which was important to him. A floor style AAC device mounting system and USB chin control were issued to Joe for AAC access when not in his wheelchair. The chosen AAC system had infrared output enabling it to function as an environmental control for lights, telephone, a door opener, and television control.

The Quebec User Evaluation of Satisfaction with Technology (QUEST)[22], [23], the Functional Mobility Assessment (FMA)[24], [25] and Psychosocial Impact of Assistive Devices (PIADS)[26], [27] outcome measures were administered pre and post of the AT intervention. Additionally, the objectives were met through demonstration in the clinic. The demonstration included the wheelchair skills test to ensure that both Joe and his fiancée could demonstrate the functionality of the PWC in its final configuration[28]–[30]. This implementation was then adapted and transferred to the home setting. Follow-up continues on a regular basis (approximately every 6 months) when Joe contacts the RE with new goals and ideas about his current assistive technology. The implementation has remained fluid and is adapted to grow with Joe's changing life. The RE is the project manager and primary point of contact for integrating Joe's technology requirements, communicating with the transdisciplinary team and assistive technology device manufacturers (RT/AT), providing technical support, and documenting quality assurance through outcome measures.

Case Study 3

A non-profit organization offering assistive technology services was hired by an insurance company to provide a solution for a 45-year-old woman with complex regional pain syndrome, resulting in chronic discomfort and pain in many places throughout her body. She was limited to lifting no more than 10 lbs and needed to avoid pinching, pulling and twisting actions with her hands, which were also sensitive to vibrations. The request/challenge was to come up with a cart that she could pull behind her while walking, without using her hand or arms. The cart would be used to transport her groceries and other items home from the store and would need to be broken down into a small profile for taking the empty cart on public transportation part of the way. To complicate matters, she lived aboard a 29-foot sailboat docked at a local harbor.

The program manager assigned this project to a staff member who was trained as a mechanical engineer and had later earned a graduate-level University Certificate in "Rehabilitation Engineering Technology." After reviewing the available background information, the RE visited the consumer at her home and carefully interviewed her about her abilities, needs, and priorities. The RE also took detailed measurements of all aspects of the environment—on the boat where she lived, the path of travel between the bus stop and the dock, and the variable pitched ramp from the dock to the boat.

The RE then broke the project down into key components and developed basic design criteria for the cart, including maximum total and component weights, overall size, load capacity, size of the cargo container, and tow arm design. Also considered were the requirements for a towing belt that distributed the weight across her hips and means of easy attachment to the tow arm, as well as how to readily assemble and break down the components.

The RE developed several iterations of rough prototypes of the individual components to test with the client and refine the design concepts and criteria. Designing suitable tipping stability into the pull cart (with three wheels for lighter weight and easier assembly and break-down) required engineering reasoning and calculations. The results informed the layout of the frame and wheels, cargo positioning, and tow arm attachment locations. Choosing materials required making load, strength, and weight calculations to help size aluminum tubing for the cart's frame, plus research into what formulations of aluminum would minimize corrosion in a marine environment.

At key points along the way, the RE consulted with an RT/AT on the staff (who also had extensive design experience) for input on alternate design concepts, help with evaluating prototypes, and ways to simplify the design to better meet time and cost constraints.

The RE happened to have experience using tools and materials and fabricated the mock-ups and rough prototypes, as well as many components of the final product. A technician skilled in metal fabrication and welding aluminum constructed the cart chassis. That person added their own improvements to the final design during the fabrication process.

Several weeks after the final product was delivered and adjusted, the RE conducted a follow-up review to affirm that the final product met the consumer's needs and expectations.

Conclusion

Rehabilitation engineering professionals play a critical role in the application of science and technology to improve the quality of life of individuals with disabilities. They work as members of the transdisciplinary team in both indirect consumer service delivery and direct consumer service delivery. The RE applies scientific knowledge and engineering design principles to produce a device, system, or process. The RT/AT complements engineering activities and lies in the occupational spectrum closer to the engineer than the RTn. The RTn assembles, configures and tests devices that have been designed by engineers, and are usually under the direct supervision of the RE or RT/AT.

The RE, RT/AT and RTn each have unique skills, knowledge and experience, which leads to a synergistic collaboration. Inherent to these unique attributes is an overlap among the professions, which promotes communication and innovation in the development and implementation of assistive technology, rehabilitation technology and universal design. The final outcome is a technology solution that improves the quality of life of individuals with a disability. It is the focus on, and collaboration with, individuals with disabilities that make the REPs unique in the engineering professions, and one of the most gratifying professions in engineering.

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Appendix

In preparation for generating the white paper, we reviewed over 80 pieces of peer-reviewed literature (primary, secondary, and tertiary) and gray literature. Though we did not utilize all of the literature in the final manuscript, we thought it was important to document the literature. Therefore, we have included a bibliography that includes the reviewed literature.

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