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Upper extremity neuro-rehabilitation through the use of power mobility

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ABSTRACT

Power mobility is typically used as an accommodative form of assistive technology allowing individuals with impaired ambulation to remain mobile. While research has focused on the cognitive development and social benefits of power mobility for individuals with developmental disabilities, research is lacking on using this technology to rehabilitate physical dysfunction. Recent technology, such as robot-mediated neuro-rehabilitation, is proving effective in upper extremity rehabilitation, but lacks the movement feedback of power mobility. This article presents a case study of a client with cerebral palsy who experienced severe neural impairment following a motor vehicle accident. As a previous power mobility user, the client identified returning to using power mobility with the affected upper extremity as a key functional goal. This case study describes the series of steps that returned the client to independent mobility and increased upper extremity function.

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Power wheelchairs have long been prescribed for persons with significant disabilities affecting mobility. The individual who is unable to ambulate and is unable to manually propel a wheelchair efficiently and effectively, can use a powered mobility device such as a power wheelchair or a scooter within the home and throughout the community. Power wheelchairs allow the users increased access to task, environment, and greater participation to roles and occupations (Buning, Angelo, & Schmeler, 2001). A power wheelchair can help promote social opportunities associated to remaining mobile (Huang, Ragonesi, Stoner, Peffley, & Galloway, 2014). Power mobility may also be used to encourage the development of cognitive skills, such as improved cause–effect, visual-perceptual and navigational concepts, and re-enforcement of consistent switch accessing methods (Nilsson, Eklund, Nyberg, & Thulesius, 2011). However, it is not well documented how a power wheelchair can be used to facilitate rehabilitation of motor control.

The following case study will describe a rehabilitation process which incorporated power mobility, as a device for providing feedback for improved motor control. Through a combination of therapy, surgery, and the use of controlling a power wheelchair, the client made significant gains in upper-extremity control following severe myelopathy due to a motor vehicle accident (MVA). Through the use of a modified power wheelchair and a variety of switches, the client was able to target specific motor skills in a way which was motivating and functional. This process led the author to wonder: can power mobility be used to help develop specific motor skills of impaired limbs? Can this be achieved by adapting the access method in a way that would require the power wheelchair user to perform a specific motor skill? Does the vestibular, visual, and auditory sensation of moving through space in a power wheelchair provide a significant form of feedback that can then be utilized as a means to help develop or restore neuromuscular function?

A similar method of rehabilitation has developed and grown in recent years mainly with stroke patients through the use of robotic or mechanical-like devices. With a device, such as the Hocoma ARMEO products, the client's affected upper extremity is placed onto a moveable or robotic "arm" (Hocoma, 2014). These devices can provide both resistance and assistance to the extremity. The client participates in a high-intensity repetitive movement regimen with the assistance of the device, at first. As the client develops active movements, the training can occur against resistance. The device has a complex array of joints, allowing it to move in the naturally occurring planes of movement of the extremity. The device can be linked to a computer, providing neuro-feedback in the form of a game or virtual software program simulating a functional task. This therapy process may be referred to as robot-based mechanical-assisted, robot-based, or robot-mediated neuro-rehabilitation. Studies of the application of robot-mediated neuro-rehabilitation have demonstrated improved outcomes in the rehabilitation process of upper extremities for clients with a diagnosis of stroke (Kwakkel, Kollen, & Krebs, 2007) and multiple sclerosis (Carpinella, Cattaneo, Abuarqub, & Ferrarin, 2009). The repetitive high-intensity therapy afforded by using these devices in place of therapists, allows the clients to receive a more consistent and effective treatment process, without increasing, or possibly decreasing the workload of therapists. Studies have

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linked robot-mediated neuro-rehabilitation to reduction in time spent in rehabilitation, a significant improvement in activities of daily living and increased productivity for the therapist, thus deeming it a better solution to traditional interventions (Turchetti et al., 2014). This technology is growing in popularity around the world, but is mostly limited by complexity of technology and of use, level of training needed, and cost (Turchetti et al., 2014).

Similarly, using a joystick or alternative access methods and modified support surfaces, a power wheelchair can be set up to allow the client to work on specific skills. By using the desired upper extremity movements to control the access method, the client will receive the vestibular and visual feedback of moving through space. There are several significant differences between commercially available robot-mediated neuro-rehabilitation and a power wheelchair; (1) the power wheelchair is not able to provide physical assistance to the limb; (2) the complexity of assisted movement of the limb is limited to the complexity and setup of how the client is accessing the drive controls of the power wheelchair; and (3) there is no visual feedback in the form of simulation in the power wheelchair. These differences are significant and thus the author is not implying that a power wheelchair is equal in its rehabilitative potential as that of commercially available robotic devices. However, some similarities exist, mainly in the form that the power wheelchair can be set up to be controlled in a way which requires the client to focus on developing specific motor skills with varying difficulty and resistance levels. Some major advantages the power wheelchair has over the stationary robotic device are that a power wheelchair is far less expensive than many commercially available robotic devices. The other advantage is that the power wheelchair provides a significantly different form of neuro-feedback. The feedback of moving through space affects the vestibular, kinesthetic, visual, and auditory system. This feedback can have a greater impact on the cause–effect learning process due to the greater sensory stimulation when compared to a computer screen (Nilsson & Nyberg, 1999). The functional difference between a virtual feedback system and actual mobility (material-based occupation) can also have an impact on the client's motivation to perform difficult physical tasks (Ross & Nelson, 2000).

As the research suggests, it can be expected that the more an individual with limited motor control uses a device such as a joystick (to control a power wheelchair), their ability to use the joystick will improve over time (Nilsson et al., 2011). It can be hypothesized that using light or no pressure sensitive switches in minimal resistance environments set up for controlling a power wheelchair can, with practice, allow the user to develop improved motor skills or motor patterns, specific to the access method being used. For example, a child with poor head control, specifically, difficulty maintaining head upright due to hypotonicity, might benefit from using a head array to control a power wheelchair. While this would not be an optimal approach to providing a child with quick access to independent mobility, it might be an effective means to improve head control, especially if mobility is a very motivating occupation for a child with no other means of acting upon his mobility. This appears to be the case in some research with children and adults learning to use power mobility while dealing with significant physical and cognitive dysfunction (Nilsson et al., 2011). The case study below outlines the process of rehabilitation for a power wheelchair user with cerebral palsy after suffering myelopathy secondary to an MVA.

Case study

K. H. is a 43-year-old female with a previous diagnosis of cerebral palsy, spastic quadriplegia. She was admitted to the hospital following an MVA while on leave from her residential program. X-rays of head, neck, shoulder, right arm, and head computed tomography (CT) showed no obvious abnormalities. K. H. was released and on the following day re-admitted to hospital due to complaints of inability to urinate, shoulder pain, and loss of upper extremity function and sensation. She was treated with pain medication, but did not regain upper extremity function or sensation. A magnetic resonance imaging (MRI) showed a spinal stenosis and myelopathy which was followed-up with a decompression laminectomy of C-3–C-6 and partial laminectomy of C-2 and C-7.

Prior to the MVA, K. H. was able to perform some functional activities with her right upper extremity. Her left upper extremity was non-functional and presented with very limited movement. She controlled a power wheelchair using a standard joystick, and fed herself using adapted utensils. She also used adapted devices, such as a computer, telephone, and meal preparation appliances. Following the MVA, K. H. presented with no function in either upper extremity.

K. H. was prescribed an increase in physical therapy (PT) services which started 2 weeks post-surgery and would eventually last for approximately 12 weeks, in addition to the ongoing services she received for her pre-existing diagnosis of cerebral palsy. The pre-existing/ongoing physical and occupational therapy services, occurring once per week, focused on addressing needs in the home environment and on addressing power mobility options. The intensive PT, occurring five times per week, focused on upper extremity function. Power mobility assessments and trainings were carried out in her existing Invacare TDX SP power wheelchair (Invacare, 2015), equipped with a custom molded seating system. The power wheelchair was modified from having the standard joystick to a driver control interface (Adaptive Switch Labs, 2014a). The driver control interface would provide a platform for trialing various access methods such as a head array and switches.

K. H. was unable to use either upper extremity, but demonstrated head control, albeit with decreased range of motion. The first access method trialed was a micro-extremity control (MEC) joystick (Adaptive Switch Labs, 2014b) mounted for chin access. While K. H. was able to use this method to move the power wheelchair, it required more fine motor isolation than she was able to perform in order to navigate the indoor spaces of the treatment clinic. This was followed by trial of a proximity sensor based head array (Adaptive Switch Labs, 2014c). The posterior sensor controlled forward, the left sensor controlled left turns, and the right sensor controlled right turns.

This system required less motor control and was less frustrating for K. H. to use. However, this setup was limited in its ability to perform fluid power wheelchair movements, requiring increased steering corrections and a fourth switch to activate reverse. Despite these limitations, K. H. saw the potential in this system and kept practicing to develop increased head control for possible use of the chin mounted joystick.

12 weeks post-laminectomy, K. H.'s therapist noted the onset of right first digit (thumb) extension. With the intensive PT sessions concluding in 2 weeks, the therapy team discussed using the newly established motor movement paired with power mobility to develop further hand function. K. H. verbally expressed great interest in the possibility of controlling the power wheelchair with her hand, and was excited to trial this concept. Simultaneously, the intensive PT sessions concluded 2 weeks after the first sign of thumb extension was noted. K. H. continued to receive the ongoing twice per week PT sessions that she received prior to the intensive PT.

Figure 1. Tash micro-light switch.

Power mobility-based neuro-rehabilitation

The first attempt of activating the power wheelchair with her upper extremity consisted of using a single-switch. A Tash micro-light switch (Ablenet, 2003) was placed directly against her thumb and was activated by minimal thumb extension. This switch requires very little pressure to activate and was joined to the driver control interface providing a "forward" command to the power wheelchair. The power wheelchair was equipped with an attendant control unit (Adaptive Switch Labs, 2015), which allowed the therapist/caregiver to provide driving commands (i.e., "right," "left," "reverse") simultaneous to the "forward" command provided by K. H. This attendant control is equipped with a reset switch, which will override and "disable" the power wheelchair, as a safety measure. This unit plugs directly into the "attendant" nine-pin port of the ASL interface. By combining the attendant control with K. H.'s "forward" command, the power wheelchair can be maneuvered through indoor/outdoor spaces with ease and safety.

The power wheelchair performance configuration was set at 15% speed, 80% acceleration, and 0% tremor dampening. The slow speed allowed for safe operation, while the high acceleration and low tremor dampening provided instant feedback of the forward motion upon switch activation. These settings were a compromise between providing sufficient feedback, while maintaining safety and not startling the client. The lag of time between switch activation and movement of the chair was minimal. This movement allowed K. H. immediate vestibular and visual feedback to the small movement created by her hand. After practicing this for 1 week, K. H. began to demonstrate a trace amount of right elbow extension. The Tash micro-lite switch was moved to the ulnar side of her hand to be activated through the use of this elbow extension (Figure 1). After practicing this for 1 week, K. H. began to perform this same task with a Jelly Bean switch (Ablenet, 2014), demonstrating an increase in strength and active range of motion of elbow extension.

Once K. H. was able to consistently activate a switch upon command, to move forward, she wanted to trial addition of left and right turns. In order to provide K. H. with a switch activation experience not requiring fine motor control and strength, the author designed and fabricated an array of proximity sensors to be controlled by her right hand. The proximity sensors (Adaptive Switch Labs, 2014d) are non-mechanical and do not require direct contact. Coming within the activation range (approximately ½ inch) of the sensor surface triggers activation. This array was mounted to an Ablenet Universal Mounting System (Ablenet, 2014). As K. H. made resistance-free movements using her right fifth digit (pinky) proximal interphalangeal (PIP) joint (in the shape of a fist) to activate the proximity switches, she was able to access right, left, and forward directions (Figure 2).

As K. H. began to develop midline, lateral, and forward hand movements originating at the elbow and shoulder joints, the next step was to trial an MEC joystick (Figure 3). Like a traditional joystick, it is proportional, thus providing smooth operation and driving characteristics; however, it is much smaller and requires much less movement deflection and force to activate. Within the first trial session, she was able

Figure 2. Custom proximity switch array.

Figure 3. MEC joystick.

to access all directions, including reverse, and navigate her indoor day-program space. At times, she had difficulty coming off the joystick to stop or negotiate obstacles and small spaces. With several days of practice she was able to navigate indoor and outdoor spaces with visual supervision. In order to promote improved access to the joystick, and accommodate for postural changes which occurred post MVA and surgery, a new custom molded seat was created to provide more consistent positioning, functional upper extremity range of motion, and better head alignment. One year post-surgery, K. H.'s power mobility control was limited only by changes in mood, affect, and energy levels, which she often attributed to "the cold weather." She was able to drive her power wheelchair with only distant supervision throughout her environments, both indoor and outdoor. She did not regain enough upper-extremity control for self-feeding, but was able to perform many of her previous occupations through environmental control systems using her right upper extremity. Her left upper extremity was non-functional prior to the MVA, and never regained any movement.

Discussion

The assumption cannot be made that K. H.'s increased upper-extremity control was solely a result of the power mobility-based training. Operative procedures for cervical myelopathy can allow for significant improvements in neurological symptoms. Research of operative outcomes suggests most marked improvements occur within the first 3 months, and up to 6–12 months for mild symptoms (Meyer et al., 2008). K. H. was receiving intensive therapy post-surgery at which time thumb extension was observed; however, K. H.'s care providers were doubtful of any further recovery in upper extremity function, due to her pre-existing diagnosis of cerebral palsy, and severe neurological symptoms post-accident. Furthermore, it appeared that K. H. had made most marked improvements in upper extremity function during the time that she participated in the power mobility based neuro-rehabilitation process. The consensus among the therapy team, was that power mobility was providing K. H. significantly more feedback for any motor actions she was capable of producing. She verbally expressed more motivation to perform in that context than in either of her ongoing physical therapy and occupational therapy sessions. It was also noted that K. H. had great difficulty producing any upper extremity movement at all, until the moment she felt the movement of the power wheelchair as feedback. These results may not be so surprising, if one considers that the motor control aspects of the brain might respond better when provided with a more sensory-rich context (Ross & Nelson, 2000).

As with many individuals experiencing severe neuropathy, K. H.'s goals were to return to her previous level of functioning. She verbally expressed her main goal was to be mobile through the use of power mobility within her residence and day program environments. The initial hope for returning to using power mobility was theoretically based on accommodation, specifically returning to using a power wheelchair with a new access method. However, through a series of small incremental rehabilitative steps and the cause–effect relationship of power mobility, the power wheelchair might have significantly contributed to the rehabilitation of motor skills. The combination of therapeutic interventions, careful positioning, sensory feedback, increased motivation, and carefully selected assistive technology access methods, allowed this individual with a significant motor impairment to re-establish some motor control and regain access to mobility.

Conclusion

While this case study describes an unusual circumstance with limited generalizability, the subject experienced a significant increase in function directly related to, or at least facilitated by, power mobility based neuro-rehabilitation. This rehabilitation process used relatively low-cost, commercially available equipment, and simple adaptations. The potential significance of mobility based neuro-feedback could potentially help many individuals who are in the rehabilitative process of an upper extremity, and are dependent upon a power wheelchair for mobility. Combined with adaptive switches, support surfaces, and modifications, the power wheelchair can have a similar therapeutic potential to that of robot-mediated neuro-rehabilitation therapies. This hypothesis requires further research with individuals experiencing physical dysfunction, such as stroke, multiple sclerosis, cerebral palsy, and neuropathy.

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