

FEASIBILITY OF A MOBILE ROBOT WITH ALTERNATIVE CONTROL SYSTEM FOR A CHILD WITH CEREBRAL PALSY

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INTRODUCTION

Independent mobility is very important in the development of typical infants, as it allows the acquisition of a broad range of skills across multiple domains. Positive changes in aspects of development have been documented in children with significant disabilities when provided with powered mobility [1,2,3]. RESNA approved a position paper in 2008 encouraging clinicians to provide early powered mobility) to appropriate children, however, electric wheelchairs are costly, impose safety risks, and traditionally have not been recommended for children until they are at least 24 to 36 months of age [4,5]. Additionally, clinicians find that many individuals who need powered mobility are unable to use existing control systems due to problems with strength, coordination, and visual acuity. The purpose of this case report is to describe the development of a safe robotic mobility device with an alternative control system designed for a three year old child with significant motor impairment.

BACKGROUND

In typically-developing infants, the initiation of independent locomotion heralds concomitant development in aspects of communicative, emotional, perceptual, cognitive, and social behavior [6,7]. With the onset of infant locomotion, parents' expectations and behaviors toward their infants also change [8], resulting in alterations of the social environment of the infant. Cortical changes in the brain are also affected by the experiential opportunities that independent mobility affords [9]. While it is not known to what degree the physical dimensions of crawling and walking, or the experiences of perceiving the world from a different and mobile perspective, or some other

phenomena are responsible for these developmental transformations, nonetheless they highlight the interconnectivity of the brain, behavior, and the environment.

Children with physical disabilities and restricted mobility have limited opportunities for exploration and socialization, and limited opportunities to exert control over their environment. In addition, they have been found to demonstrate increased dependence, apathy, lack of curiosity, frustration, depressed motivation, and a lack of confidence [1]. Researchers have reported that when children with disabilities have received powered mobility, they have achieved increased independent movement, greater environmental interaction, a more positive affect, increased motivation, more confidence, increased social contact, and improved communication [1,2,3].

Many therapists and researchers believe that young children with disabilities should be considered for receiving powered mobility as early as is feasible. However, authors of a survey of clinicians [10] estimated that up to 26 percent of the clinicians' clients who desired powered mobility were unable to use existing control systems. Estimation of wheelchair users who would benefit from at least some of the time from a "smart wheelchair" (a mobile robot base with an attached seat, or standard electric wheelchair with an added computer; they may include alternative controls and/or sensors) ranged from 61 to 91 percent [11]. In the case of cerebral palsy, the most common cause of motor disability in children, the estimation ranges from 70 to 90 percent. Descriptions of provision of smart wheelchairs systems for children are very limited in the literature.

DESCRIPTION OF THE CASE

Participant

We are working with a 3 year old boy with cerebral palsy, with spastic and athetoid features. The child's gross motor mobility is limited to rolling from supine to prone; he is unable to maintain head control or sit without external support. He is nonverbal, produces sounds. He appears to understand spoken language well, and communicates by indicating yes or no by reaching toward the signed or written word. He is able to identify all letters of the alphabet, and can recognize and spell many words. He is working with a DynaVox speech generating device, but skills are not yet functional due to severe motor incoordination. The child has significant gastroesophageal reflux; he receives all food and liquid nonorally, and experiences frequent vomiting.

Description of the Mobile Robot and Alternative Control System

Our mobile robot consists of a commercial-off-the-shelf Pioneer 3DX robot with two on-board computers — one controls the robot while the other runs the custom software developed for this project. Sonar rings containing eight sonar sensors each are attached to the front and rear of the robot. These are used to detect obstacles and prevent collisions. A wireless gaming joystick allows an adult to control the robot for additional safety, and to assist the child when necessary. The robot is surrounded by a custom-fabricated "carriage" with six casters that supports a commercially-available seat. The seat has been modified to provide better support for the child with the addition of a pelvic strap and a head support. The seat supports our control system, which consists of four "Buddy Buttons" (for forward, reverse, left, and right robot movements) arranged on a tray placed in front of the child at lower-chest level.

The buttons communicate with the robot's on-board computer through a USB switch interface (also commercially available). Software allows us to record xy data to track robot movement, and to control speed in forward and backward directions, and angle

increments for turning to the left and right to meet the child's needs.

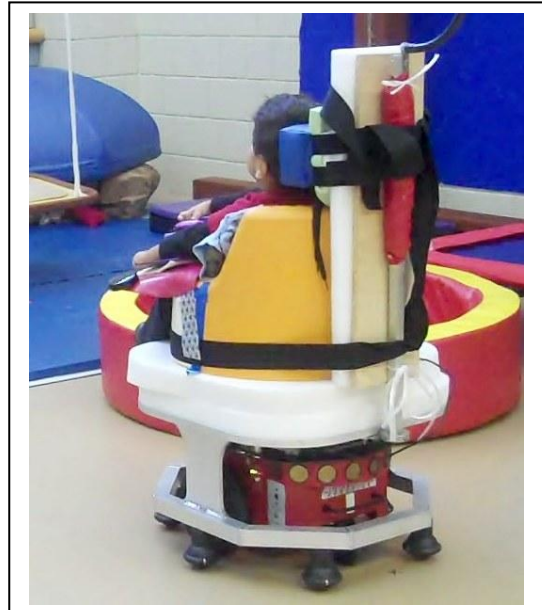


Figure 1: The Pioneer 3DX robot with carriage, adapted seating, and controls

For this child, the back button is situated to the child's left, to be activated with his left arm/hand. The remaining buttons have been arranged toward the child's right, to be activated with his right hand/arm (which is the more reliable upper extremity), in a "stepped" pattern, with the button directly in front of the child in the highest position, with the two remaining buttons each approximately 1.5 inches lower than the button to its left. The buttons are configured for direct control (un-latched).



Figure 2: Buddy Button controls

Training

We worked with the child once per week for 45 minutes to 1.5 hours in our lab at Ithaca College. We began in late September of 2010, with a break between semesters of three weeks. During this time period we moved the robot to the family's home, following training in using the robot safely. We plan to continue our intervention until February of 2011. Much of the time in the early weeks was devoted to developing a seating system that supported the child adequately (an on-going problem) above the robot, and to developing a stable arrangement for mounting the buttons for the control system. We developed a program based on motor learning principles for training the child in the use of the control system, with fading prompts, verbal reinforcement to provide knowledge of performance, and a data system to provide knowledge of results to the child (and to reward the child's efforts with books and videos with points gained). Our initial plan was to follow the brief training program with data collection and a free play period of 20-30 minutes short training program. We planned to collect data on time to initiate forward movement on command, time to respond to a command of stop, ability to negotiate a straight course, and degree of error in turning toward a target. We recorded every session in digital video from a digital video recorder on a tripod at the level of the child, and from a digital video recorder mounted above the child on a gooseneck (to capture upper extremity movement more accurately).

Results

The system's performance has been consistent and reliable. There are two issues which present some concern to us. The first issue is that when beginning forward movement following a turn, the robot's rear caster realigns itself which results in a slight lurch, so that the robot's movement is at a slight angle from the desired trajectory. The second issue is that the weight of the child and the seating system are at the limit of what the robot effectively carry, which limits our ability to modify the seating system to fully meet the child's positioning needs.

The child learned how the robot system functioned very quickly. Modification of the system in the first several weeks resulted in differing arrangements of the button controls, His performance with the system has been uneven. We were unable to institute a consistent training program or data collection protocol due to significant intolerance by the child to this aspect of the intervention, which has frustrated our attempts to collect reliable data on performance. When asked to perform on command, he consistently reacted by crying. However, observations during sessions and upon review of video data indicate that his driving ability is fair when he is motivated to perform.

His control is best when engaged in activities he enjoys (such as driving toward a suspended platform for a swing, driving to knock over cardboard block structures, or driving to collect letters to spell out words). He can position his arm over the forward button (the middle button on the right) without difficulty, but does not always remove it to stop forward movement before he reaches an obstacle or his target (instead, the sonar stops the robot). He requires reminders to "turn", and frequently initiates turning in the wrong direction. Due to posturing of the forearm, wrist, and fingers upon reaching toward the buttons, he sometimes is not able to activate the button even though his arm is resting over the desired button, which appears to be frustrating and confusing for the child. Changing his movement from one switch to another is difficult for the child due to trunk, head, and upper extremity extraneous movement. The child fatigues easily; controlling his movements requires significant concentration and effort.

Discussion

Despite these obstacles, the child is almost always willing to work with the robot, and his parents are encouraged by his ability to move independently. We have observed that the child appears not to be interested in movement for its own sake (as typically-developing children would be expected to do, although perhaps at a younger age), and does not attempt to interact with the robot except when he has a desire to drive to a specific location for a clear purpose.

While we have been troubled at times by his unwillingness to participate in a training protocol, it is perhaps understandable in that his ability to exert control over life events is very limited—through his refusal he has found a very effective manner of gaining control.

While we are satisfied with the performance of our system, we do not believe that our seating system optimally supports and facilitates the child's function. For optimal upper extremity function in children with severely limited motor function with cerebral palsy, positioning to support function is crucial [12].

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