


2009

## Powered mobility as an intervention for children with cerebral palsy: A systematic review ; The smart wheelchair: Is it an appropriate mobility training tool for children with cerebral palsy?

Sarah McGarry  
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Powered mobility as an intervention for children with cerebral palsy: A systematic review

AND

The Smart Wheelchair: Is it an appropriate mobility training tool for children with cerebral palsy?

Sarah McGarry

A report submitted in Partial Fulfilment of the Requirements for the Award of Bachelor of Science (Occupational Therapy)(Honours), Faculty of Computing, Health and Science,

Edith Cowan University.

Submitted (September, 2009)

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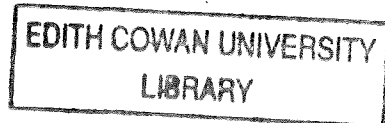
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## ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to all those who supported me in the completion of this study.

Firstly, to the children and parents who participated in this study. Thank you for volunteering your time and sharing this experience with me. Sincere thanks to The Centre for Cerebral Palsy for their support and for making this research possible.

I would like to especially thank my supervisors Dr Sonya Girdler and Lois Moir for their constant support, guidance and encouragement. I really appreciate all the time and effort you both spent on this project and, I am thankful to have the experience of working with two inspiring and motivational occupational therapists.

Finally, thank you to my family for their constant support.



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Powered mobility as an intervention for children with cerebral palsy: A systematic review

Sarah McGarry

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**Abstract**

*Purpose.* To systematically review the effectiveness of powered mobility training interventions in improving driving skills and psychosocial outcomes in children with cerebral palsy.

*Method.* Electronic searches of CINAHL, Medline and Meditext were conducted. Using two assessment tools, two independent reviewers assessed the quality of selected studies and level of evidence. Studies were included if a powered mobility training intervention was described, at least one participant had cerebral palsy and if the majority of participants were aged between 18 months and 18 years old. A narrative analysis was conducted.

*Results.* Seven articles were eligible for inclusion. Intervention protocols included computer simulator training, mobility training on a powered riding toy, and a powered wheelchair. The quality of the studies ranged from strong to limited, with six out of seven studies rated as level IV evidence and one study rated as level III evidence as defined by the National Health and Medical Research Council level of evidence table.

*Conclusions.* Although research is limited observational investigations suggest that powered mobility training programs are potentially beneficial in the development of driving skills for children with cerebral palsy and may have a positive impact on psychosocial outcomes. Methodological weaknesses of the studies were small sample sizes, absence of control groups and largely descriptive data analysis. There is a need for future, more rigorous research which addresses these weaknesses and contributes to an understanding of the utility of powered mobility both as a method of access and as a therapeutic intervention tool.

*Key Words:* powered wheelchairs, electric wheelchairs, mobility interventions, children with disabilities

Sarah McGarry,

Dr Sonya Girdler,

September, 2009

## Powered mobility as an intervention for children with cerebral palsy: A systematic review

### **Introduction**

Cerebral palsy (CP) is the most common physical childhood disability [1-3], accounting for 600 to 700 Australian births each year [1]. Improvements and advances in perinatal care are associated with declining rates of infant mortality among pre term infants and increasing numbers of infants born with CP [4-5]. It is estimated that 33,797 Australians have CP and this number is expected to increase to 47,601 by 2050 [1]. In 2007 the financial cost of CP in Australia was estimated to be \$1.47 billion [1]. This value increases to \$2.4 billion when considering the value of lost wellbeing, due to disability and premature death [1]. The per annum financial cost of CP is \$43,431 per person. Including the value of lost wellbeing the cost increases to \$115,000 per annum, per person [1]. With increasing numbers of children born with CP, there is a need to understand effective therapeutic interventions as demands on services will increase.

Cerebral palsy is a neurological condition referring to a group of permanent disorders affecting the development of movement and posture [6]. In addition many individuals experience limitations in cognition, communication, sensation and perception [6]. The severity of CP can vary, with motor and cognitive impairments ranging from minimal to profound [7,8]. The functional limitations that result from CP mean that children are dependent on their carers for many aspects of activities of daily living, instrumental activities of daily living and mobility [2,7,8]. It is estimated that 35 percent of the population with CP are also severely cognitively impaired, leading to reduced ability to care for themselves and others [9]. Restrictions in social interactions increase progressively with impairment type and severity level of CP [10,11]. These functional limitations may impact participation in meaningful activities and in the fulfilment of social roles.

Developmental theorists propose that early experiences of movement impact on physical and psychological development [12,13]. Piaget [14] believed independent movement to be an important

building block for the development of knowledge. Locomotion encourages a child's understanding of space, objects, self awareness, and principles of cause and effect [14,15]. In addition, independent movement allows a child to gain a sense of independence and competence, as well as providing opportunities to learn and socialise [15,16]. Supporting this stance, research has demonstrated that for children, gains in mobility are linked with improvements in cognitive, social-emotional, perceptual and motor functioning [13,17,18].

Many children with CP are unable to independently mobilise due to cognitive and motor impairments [8,19]. These children rely on care givers to move them from place to place, and consequently miss many crucial learning opportunities. This impacts negatively on their skill development in the areas of cognition, behaviour, emotion and communication [20-22]. Secondary developmental problems can result from a child's increasing frustration at their inability to control the world around them [23]. This often results in a cycle of deprivation, and reduced motivation [24].

Powered wheelchairs can provide children with CP the opportunity to explore their environments through play and locomotion [19] and decrease their dependency on others [19,25]. Despite the importance of independent mobility in child development and the wide use of powered wheelchairs in clinical settings for children with disabilities, little attention has been given to the evidence base underpinning powered mobility interventions. The purpose of this systematic literature review was to examine the effectiveness of powered mobility training interventions in improving driving skills and psychosocial outcomes in young children with CP.

## **Methods**

Principles and techniques of systematic reviews were used to review the literature and locate relevant studies for inclusion. Electronic searches of CINAHL, Medline and Meditext were conducted. Each database was searched from its earliest records to most recent (CINAHL 1937- 2009, Medline 1948-2009,

Meditext 1968-2009). The main search terms included a combination of both participant (children, young children and cerebral palsy) and intervention terms (powered mobility, powered wheelchairs, powered mobility training and mobility aids). All search terms were truncated, exploded and adjusted to match the identified databases with assistance from a librarian. Reference lists of all retrieved articles were manually searched for relevant articles. The literature search was limited to peer reviewed (English language) published data only, and excluded grey literature and expert opinion.

*A priori* criteria for inclusion of studies were applied to identify abstracts and then full text articles. Studies were included if a powered mobility training intervention was described. The mode, length and frequency of the interventions were not limited. Due to the paucity of studies describing powered mobility interventions with children with CP, studies were included if at least one participant had CP. Studies were limited to those with the majority of participants aged 18 months - 18 years old. Outcomes of interest included driving skills and psychosocial outcomes related to powered mobility, for example improvements in confidence and independence.

#### *Assessment of methodological quality*

Using an assessment tool developed by Kmet, Lee and Cook [26] two independent reviewers assessed the quality of the selected studies. The assessment consists of 14 questions and a scoring system for methodological quality. Using this system each study was categorised as strong (score of >80%), good (70-80%), adequate (50-70%) or limited (<50%) [27].

#### *Data extraction*

Two reviewers used methods set out in Section 7 of the *Cochrane Handbook of Systematic Reviews of Interventions* [28] to extract relevant data from the studies. Data extracted included: study objective(s), study design, method of participant selection, characteristics of the participants, random allocation, masking of the investigators, masking of the participants, outcomes, sample size, analytical methods,

estimate of variance, confounding controls, results and conclusions. Once data was extracted the level of evidence was determined based on the National Health and Medical Research Council guidelines (NHMRC) [29]. Discrepancies between reviewers were resolved through discussion.

### *Data synthesis and analysis*

Due to the use of non traditional analysis of methods such as parent interviews and video footage, and small sample sizes in the articles, meta-analysis was not possible. A narrative review was conducted to summarise findings and provide an assessment of methodological issues.

## **Results**

Electronic searches located 21 articles from CINAHL, five from Meditext and 22 from Medline. A total of 39 potential articles were located after duplicates were accounted for. Using the stated inclusion criteria, abstracts and full texts were reviewed, resulting in seven articles judged as eligible for inclusion. Excluded papers included expert opinion, descriptions of the use of powered wheelchairs with adults and children, discussions on types of wheelchairs and assessment practices, and descriptive data about the perspectives of parents and providers.

Articles meeting the selection criteria ranged in publication date from 1983 to 2003. Of the seven articles selected two were written by the same authors, and one author is responsible for three papers. These three papers were published in 1983, 1984 and 1986, an average of 25 years ago. One article was published in 1998, and the remaining three articles were published in 2001, 2002 and 2003, a minimum of six years ago. All studies investigated a powered mobility training intervention with a total of 83 participants. Intervention protocols of these articles included computer simulator training to improve powered wheelchair driving, mobility training on a powered riding toy and mobility training on a powered wheelchair.



### *Quality assessment of studies*

Assessment of methodological quality of the research ranged from strong to limited (see appendix D). A study investigating powered wheelchair training in the home was rated as methodologically limited (27%) [30], four separate studies reporting on a mobility toy, the use of a computer simulator to increase driving skills and powered mobility training in the home, were rated as adequate (50-68%) [31-34], and two studies examining the concept of driving to learn and powered wheelchairs for independence were rated strong [35-36]. Overall, methodological weaknesses of the studies were small sample sizes, absence of control groups, lack of blinding, and largely descriptive data analysis. In clinical research that requires the active involvement of participants these weaknesses are common and can be difficult to overcome. Authors did not report effect size or describe controls used for confounding, and three authors did not report estimates of variance for the main results. Apart from one study, psychometric properties of the outcome measures used were not described. The NHMRC [29] level of evidence table was used to rank studies according to four levels. Level I is the strongest and most rigorous, accounting for systematic reviews of all relevant randomised control trials. Level IV is the least rigorous, consisting of evidence obtained from case series, either post test, or pre test and post test [29]. Six out of seven studies included in this review were rated as level IV evidence and one study was rated as level III evidence, due to the inclusion of a comparison group (see appendix D).

### *Interventions*

The reviewed interventions were powered mobility training programmes for children with CP and other disabilities. Three studies assessed the participant's ability to learn to drive a powered wheelchair at home under parent supervision [30-32]. Another study evaluated power wheelchair training in a clinic setting and at home [36]. In a cohort design study using a computer simulator, children navigated a game of mazes with a joystick [34]. Lastly, a powered mobility riding toy was used as an intervention in a single subject withdrawal design study of two children aged five years old [33]. One study failed to provide

details about the powered mobility program [35] and no studies described explicitly the strategies used to promote intervention fidelity.

Several studies attempted to employ control strategies to provide a baseline of comparison, to support the interpretation of the effect of the intervention [37]. The use of a comparison group was evident in only one study [34]. This study investigated whether training on a computer simulator would increase the driving skills of children who had never used a powered wheelchair in comparison to children who were experienced drivers. A single subject design with multiple baselines was described as successful in using the participants as their own control [31]. Whereas a study using a case history survey design argued that the use of a control group would be unethical as they believed it would be detrimental to the participants to delay provision of a powered wheelchair [35].

### *Outcomes*

In five of the seven studies powered wheelchair driving skills were measured as the primary dependant variable [30,32,34,-36]. One study described frequency of self initiated physical interaction with objects, communications with care giver and changes in location in space as dependent variables [31] <sup>1</sup>. Similarly, Diatz and colleagues [33] reported child initiated movement, child initiated contact with others, and affect as dependent variables. Psychosocial outcomes were measured in five of the seven studies; outcomes included social, emotional and intellectual behaviours, level of independence, and development of initiative and exploratory behaviours [30,31,33,35,36]. Video footage, a seven skill driving checklist, Powered Mobility Program assessment battery [38], and a computer game were measures used to assess participant's driving skills. Five out of the seven studies utilised parent interviews to enrich their quantitative findings [30,32,33,35,36]. To investigate the effect of early provision of powered wheelchairs Bottos and colleagues [35] employed standardised measures, including Impact of Childhood Illness Scale, Gross Motor Functional Measure, the Canadian Occupational Performance Measure, Performance IQ

score of the Leiter International Performance Scale, and Verbal IQ score of the Peabody Developmental Verbal Scale.

Collectively the results of the five studies measuring the driving skills of participants suggested that children and young adults aged from 23 months to 22 years old with physical and cognitive impairments can learn to drive a powered wheelchair independently, with a minimum training time of 16 days and within a maximum training time of one year [30,32,34-36]. Five studies evaluating psychosocial outcomes found independent powered mobility promoted increased social interaction, increased motivation to move and interact with the environment, and increased independence [30,31,33,35,36]. Independent powered mobility did not affect motor impairment, Intelligence Quotient or quality of life [35]. However, powered mobility was linked to an increase in exploratory behaviours, initiative, and ability to react to external stimuli [36]. Qualitative findings supported the conclusions that powered mobility stimulated the child's understanding of cause and effect relationships, encouraged limited use of participant's arms and hands, as well as stimulated the child's level of alertness [36].

Three studies reported statistically significant changes following the powered mobility intervention. Participant's driving skills improved significantly ( $p < 0.01$ ) in two studies [34,35]. An increase in self initiated change in location ( $p < 0.05$ ) was found to be associated with independent driving of a powered wheelchair [31], as was changes in occupational performance, measured by the Canadian Occupational Performance Model ( $p < 0.00001$ ) [34,35].

## **Discussion**

Overall this systematic review found a paucity of evidence to support powered mobility as an intervention for children with CP. Findings from level III and IV evidence suggest that young children with physical and cognitive disabilities can learn to drive a powered wheelchair and a powered riding toy independently. In addition, improvements in psychosocial outcomes were found to be associated with independent

powered mobility. However, the reviewed research has many methodological limitations, being based on small sample sizes and largely descriptive data analysis. Many of the studies excluded from the review were published by clinicians and consisted of 'expert opinion'. Although papers in this category are valid contributions to literature in this area, they are viewed as the least rigorous in terms of evidence and are susceptible to bias [39,29]. Evidence gained from this literature review was limited as the majority of the studies were of adequate quality and were ranked level IV evidence, which can only allude to a causal relationship between the independent and dependent variables [29].

The studies reviewed varied considerably in intervention, study design, and outcome measures making it difficult to draw collective conclusions from the results. In depth descriptions of intervention protocols were absent and intervention fidelity was not accounted for in the studies. However, a number of studies used both qualitative and quantitative methods, an approach which has been described as having merit in this field of research [39]. Four studies used a single subject design, limiting the inference of outcomes to groups or situations other than those directly involved in the study [37]. Further, the reliability and validity of the findings are questionable given that authors did not discuss the psychometric properties of the outcome measures and only one study used standardised assessments [35]. When evaluating the impact of powered mobility devices for children with CP there is clearly a need for higher quality, more rigorous research involving larger sample groups, a comparison group, and standardised measures to produce adequate evidence for therapists and families.

Over the past three decades, the development of new assistive technologies for individuals with disabilities has increased [40,41]. Using the latest technologies and robotics, new models of wheelchairs such as the CALL Centre Smart Wheelchair and the Collaborative Wheelchair Assistant have been developed [42,43]. This systematic review found that there is a very scarce evidence base for the use of technologically advanced models of powered wheelchairs with children with CP. Of the seven articles reviewed three were at least 25 years old, with the most recent study in the review being six years old.

This suggests that this evidence is from powered wheelchairs that are since outdated and possibly no longer prescribed to children. There is a clear need for current research using the latest most advanced models of powered wheelchairs which may be suitable to a wider population of children with various disabilities.

The notion of 'driving to learn' was discussed in a study evaluating powered mobility for children with profound cognitive disabilities [36]. This method of training is based on the notion that mobility can be used as a therapeutic tool, rather than purely a means of gaining access between one place and another. It is proposed that the sensory stimulation and change of body positions resulting from powered mobility can raise the individual's alertness, enhancing their ability to understand simple causal relationships [36]. This method of training may be useful for uncovering skills and abilities previously unrecognised in children with severe and multiple disabilities. Further the full mobility potential of children who may have previously been excluded from powered wheelchair training may be revealed. Given the potential of driving to learn for many children and their families, there is a great need to further investigate this concept.

Findings from this systematic review highlight the need for future research to evaluate the relationship between powered mobility and the components of the World Health Organization's International Classification of Functioning, Disability and Health framework [44]. The development of targeted interventions to enhance independent powered mobility for children with CP will depend on a clearer understanding of the link between body structures and functions, activity, and their impact on participation [39]. In doing so the impact of contextual factors such as environment and personal factors on powered mobility interventions can be explored enabling an understanding of the length of training required, potential discontinuation of mobility devices, and a much broader perspective of the impact powered mobility has on an individual's life [25].

Although a systematic search strategy was applied, the authors acknowledge that conclusions may be affected if relevant studies were unintentionally overlooked. Another limitation of this paper is that many studies in the field of powered mobility are not published in peer reviewed journals but appear in conference proceedings. The selection criteria excluded grey literature therefore these studies were not reviewed.

Although many experts in the field have advocated for early provision of powered wheelchairs for young children, the gap between research and practice continues. The existing evidence base for effective powered mobility interventions is limited however, the weight of the evidence suggests a positive relationship between powered mobility and child development. Limitations in the current body of knowledge outline directions for future research. Future studies should incorporate current clinical practices and examine intervention effectiveness not just for improvement of isolated mobility skills, but to gain a greater understanding of interventions that can contribute to the development of children with cerebral palsy.

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## Guidelines for contributions by authors

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$$\frac{6l + 5h + g}{3n + 3yz^2}$$

But:  $\underline{a/b + c/d + a/d}$



$$P = (a^2 = b^2)(c^2 + d^2)$$

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[3] Irvin AD, Cunningham MP, Young AS, editors. *Advances in the control of Theileriosis*. International Conference held at the International Laboratory for Research on Animal Diseases; 1981 Feb 9-13; Nairobi. Boston: Martinus Nijhoff Publishers; 1981. 427 p.

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[5] Loker WM. "Campesinos" and the crisis of modernization in Latin America. *Jour of Pol Ecol* [serial online] 1996; 3(1). Available: [http://www.library.arizona.edu/ej/jpe/volume\\_3/ascii-lokeriso.txt](http://www.library.arizona.edu/ej/jpe/volume_3/ascii-lokeriso.txt) via the INTERNET. Accessed 1996 Aug 11.

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[6] *British Medical Journal* [Internet]. Stanford, CA: Stanford Univ; 2004 July 10 - [cited 2004 Aug 12]; Available from: <http://0-bmj.bmjournals.com.library.ecu.edu.au:80/>

## Internet databases:

[7] *Prevention News Update Database* [Internet]. Rockville (MD): Centers for Disease Control and Prevention (US), National Prevention Information Network. 1988 Jun - [cited 2001 Apr 12]. Available from: <http://www.cdcnpin.org/db/public/dnmain.htm>

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The Smart Wheelchair: Is it an appropriate mobility training tool for children with cerebral palsy?

Sarah McGarry

## The Smart Wheelchair: Is it an appropriate mobility training tool for children with cerebral palsy?

### **Abstract**

*Purpose:* To describe the impact of a mobility training program using the Smart Wheelchair on the driving skills and psychosocial outcomes of children with cerebral palsy.

*Method:* A multiple case study design using mixed methods was used. Four children with cerebral palsy were recruited for the study. The intervention was a Smart Wheelchair mobility training program. Data was collected using a quantitative driving skills assessment, field notes and qualitative parent interviews.

*Results:* Three out of four children gained independence in at least three driving skills or more, whilst one child was competent with verbal prompts. Three out of four mothers reported positive changes in their child's confidence, motivation and affect.

*Conclusions:* The Smart Wheelchair has the ability to uncover learning potential and facilitate the recognition of abilities in children with cerebral palsy previously excluded from access to independent mobility. Given the significant limitation that restrictions in mobility pose to participation for children with cerebral palsy, occupational therapists must begin to understand the effectiveness of interventions such as the Smart Wheelchair. The descriptive findings of this study allow for future, more rigorous research, to be conducted on the effectiveness of the Smart Wheelchair as a mobility training tool.

*Key Words:* powered wheelchairs, intelligent wheelchairs, mobility interventions, children, cerebral palsy

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September, 2009

## The Smart Wheelchair: Is It an Appropriate Mobility Training Tool For Children with Cerebral Palsy?

### Introduction

Cerebral palsy (CP) is the most common physical childhood disability [1-3], accounting for 600 to 700 Australian births each year [1]. Advances in perinatal care have been associated with declining rates of infant mortality among pre-term infants and an increase in the number of infants born with CP [4,5]. It was estimated in 2007 that 33,797 Australians have CP and this number is expected to increase to 47,601 by 2050 [1]. This increase in absolute numbers of Australians living with CP will result in a corresponding increase in demand for effective therapeutic interventions.

Many children with CP are unable to independently mobilise and consequently miss many crucial learning opportunities. This impacts negatively on their skill development in the areas of cognition, behaviour, emotion and communication [6-8]. Secondary developmental problems can result from a child's increasing frustration at their inability to control the world around them [9]. Mobility impairment therefore often results in a cycle of deprivation, and reduced motivation [10].

Many children with CP are unable to operate a powered wheelchair (PWC) due to difficulties in motor and cognitive domains [11]. Children with CP have often been excluded from powered mobility research as they typically have higher learning needs compared to other children with developmental disabilities [12]. Clinically, therapists are confronted with the challenge of assessing whether a child is eligible for powered mobility training, and if they are not, what further options are available for mobility [13]. In 2005 a national survey of providers of paediatric PWCs in the USA, found that cognitive, physical, and behavioural factors were the three main reasons therapists did not refer children with disabilities for a PWC [14].

Occupational therapists assist individuals to perform meaningful and functional activities in order to enhance occupational performance and play an important role in facilitating the learning process for

children to develop motor skills [15]. Motor learning theory can be used by occupational therapists to conduct occupation-based interventions that are meaningful to individuals [16]. Many researchers suggest that programs enhancing functional abilities for children with developmental delays should include motor learning theory [16-18]. Motor learning theory facilitates skill acquisition as a result of practice and experience [19]. Feedback and repetition are the two key strategies used to facilitate skill acquisition [19], and it has been noted that children with CP respond well to this approach [18]. The use of feedback allows the therapist to be a responsive partner in therapy whilst maintaining a child centred approach [17,20,21]. Occupational therapists can use motor learning theory to develop mobility training programs for children with disabilities.

The Smart Wheelchair is a mobility option for children who are considered to not have the prerequisite skills required to drive a PWC. The Smart Wheelchair is an augmentative mobility aid equipped with specialised sensors and a computerised control system. Functions of the chair include collision sensors and a line follower, allowing the user to navigate difficult environments with the use of a single capacity switch [22,23]. The aim of the Smart Wheelchair is not to replace the user's abilities with technology, but to complement and expand the user's skills [22]. The Smart Wheelchair can be viewed as a therapeutic tool as its objective is not only to allow the child to move from one area to another, but to learn new skills and progress developmentally. It has been proposed that using the Smart Wheelchair in combination with a clinical assessment tool, therapists are able to evaluate how far along the mobility continuum a child has progressed [22].

There is a need for new technologies such as the Smart Wheelchair to be evaluated. To date the inventors of the CALL Centre Smart Wheelchair are the only researchers to publish a study investigating the use of this wheelchair with children with motor and cognitive disabilities [10]. Given that the number of children living with CP is expected to increase in coming years and the significant impact that restrictions in mobility has on development, research must begin to evaluate the effectiveness of interventions such as



the Smart Wheelchair. Understanding the effectiveness of technologically advanced PWCs in maximising the mobility of children with CP has the potential to reduce the burden of disability associated with CP. There is a need for therapists and families to gain an understanding of the utility of the Smart Wheelchair, both as a method of access and as a therapeutic intervention tool. The purpose of this study was to describe the impact of a mobility training program using the Smart Wheelchair on the driving skills and psychosocial outcomes of children with CP.

### **Materials and Methods**

This study employed a multiple case study design using mixed methods. Case studies are a suitable approach to explore, describe and explain complex phenomena within their natural context [24,25]. Case studies are appropriate designs to evaluate interventions in health science research because of their rigor, flexibility [24] and direct applicability to patient care [26,27]. Evidence from multiple case studies is often considered to be more robust and compelling compared to single case studies due to the replication of patterns and trends [25].

A mixed method approach to data collection was utilised in this study as it facilitates the collection of information from multiple perspectives, allowing a greater understanding of the research topic [28,29]. The purpose of using mixed methods was complementarity which allowed facets of the research phenomenon to be measured, facilitating an enriched and elaborated understanding of the phenomenon [28]. Ethical approval was obtained from the Edith Cowan University Human Research Ethics Committee and the Centre for Cerebral Palsy (TCCP).

Children in this study were recruited through TCCP. TCCP is a not for profit charitable organisation which provides services and support to more than 1000 individuals with CP and their families. Literal replication logic was used to select participants. This permitted the researcher to select cases that were similar allowing patterns in the data to emerge, enhancing the transferability of the evidence collected

[25,30]. Four participants were deemed adequate to allow for replication within case studies [25]. Informed consent was gained from all participant's legal guardians and all participants were: 1) aged between four and fourteen years; 2) diagnosed with cerebral palsy; 3) classified as level V on the Gross Motor Functioning Classification Scale [31]; 4) had minimal to extensive experience using a switch; and, 6) had never been exposed to a Smart Wheelchair.

### *Intervention*

Each participant took part in the Smart Wheelchair Mobility Training Program (SWMTP). The intervention protocol for this program is outlined in appendix A. The SWMTP was conducted at TCCP and consisted of two one hour sessions per week (on consecutive days), for eight weeks. The researcher, a fourth year occupational therapy (honours) student conducted the SWMTP with supervision and guidance from an experienced occupational therapist. Activities in each session were aimed at encouraging the driving skills of the children, and were based on motor learning theory [19]. Motor learning theory supported a focus on motor skill acquisition and the learning process of these skills. An important component of motor learning theory is the therapist's use of feedback [32]. To facilitate skill acquisition the therapist provided extrinsic feedback both verbal and physical, combined with structured practice to illicit an intrinsic feedback response in each child [32]. For four weeks, the sessions were held in a large room with toys to increase the child's motivation and basic mobility skills. As the child's abilities progressed sessions were held in the school environment, and outside areas to enhance functional driving skills.

### *Driving skills*

Driving skills were measured using the Powered Mobility Program assessment battery, adapted (with permission) to reflect the use of a switch control rather than a joystick in basic mobility skills [33]. The adapted assessment was piloted with a child (not enrolled in the study) meeting the inclusion criteria [25]. In administering the assessment the researcher observed each participant driving the Smart Wheelchair for

a minimum of 45 minutes and scored the assessment according to the highest observed level of skill. For example a score of one is given if a child requires maximal hands on assistance compared to a score of 5 which equates to the child conducting the skill independently with age appropriate supervision. Skills observed included basic cause and effect association, contacting the switch to engage the wheelchair in motion, maintaining contact with the switch for continuous driving, looking in the direction of movement, turning in one or two directions and stopping on command and spontaneously to avoid objects (see appendix B). During each intervention session the researcher recorded field notes which included observations of changes in the child's behaviour, important events and the physical setting of the environment [34].

#### *Psychosocial outcomes*

In order to describe psychosocial changes for each child semi-structured interviews were conducted with parents. Five open ended questions addressing the impact of the SWMTP on changes in communication, behaviours, motivation, affect, and initiation formed the interview guide, which while allowing for flexibility helped to centre the interview on the area of inquiry (see appendix C) [35]. The interview guide was piloted with a parent of a child with CP participating in a Smart Wheelchair clinic but not enrolled in the present study [36]. Parent interviews were conducted by the researcher after the completion of the SWMTP. Each interview was face-to-face in nature and conducted at TCCP or the parent's home. The interviews were recorded using a voice recorder.

In order to describe changes in driving skills, data was entered into Microsoft Excel to produce line graphs [26]. For each participant a total average score was calculated for the first and last session [26]. Inductive analysis and reflexive interpretation of the field notes occurred at the completion of data collection in order to search for meaning and patterns within the data [34,37].

Parent interviews were transcribed verbatim onto a secure computer and compared with field notes taken during each interview. Individual interviews were analysed using narrative analysis to reduce the data and develop a summary of the phenomenon researched [35,38]. Narrative analysis can assist occupational therapists to gain an enhanced understanding of the participant's experience of the therapeutic process [38]. The credibility of the interview findings was enhanced by member checking with one parent to verify data and interpretation [39].

The trustworthiness of this study was enhanced by triangulation of data collection, literal replication logic to select participants, peer debriefing, member checks, field notes, an audit trail, and piloting of data collection tools [39,40].

## **Findings**

Four children meeting the selection criteria were recruited. The participants in this study represent children typically excluded from powered wheelchair access. Participants ages ranged from five to 13 years. All participants lived at home with their parents and three of the children attended respite care regularly. Case studies are presented in the form of vignettes and pseudonyms were used to maintain confidentiality.

### David

David was a 13 year old boy with West Syndrome, bilateral astigmatism, central hypotonia with mild peripherally increased tone, and an intellectual disability. David was dependent on his parents and carers for all activities of daily living (ADL) and communicated with vocalisations. He attended a WA Department of Education Support School. David experienced regular seizures which impacted on his level of alertness and it was unknown whether David understood cause and effect relationships.

In the past David's switching had been unreliable and his therapist was unable to recommend a consistent switch site. Due to ill health David attended 11 of the 16 SWMTP sessions. David's switching improved with a large plate switch covered in tinfoil to incorporate sensory stimulation. He was encouraged to use his right hand to reach forward to activate the switch with his fingers. David required hand-over-hand prompting in the first session and became very excited, shouting loudly and banging his head. In the second session of the SWMTP David responded well to the Smart Wheelchair, he was alert and activated the switch independently, with verbal prompting, three times. For the next five sessions David required mostly hand-over-hand prompting to activate the switch, and encouragement through verbal feedback. During the sessions David was alert and responsive to his environment. In the last four sessions with constant repetition, motivational toys, and intrinsic and extrinsic feedback, David switched independently, looked in the direction of movement and demonstrated an understanding of cause and effect. For example, David was able to activate the switch three times to reach his favourite toy. In each of the categories presented in graph 1, David improved from a score of 0 (not attempting the task) to 4 (verbal cuing only). In the first session David's total average score on the driving skills assessment was 0.09 compared to the last session where he scored 1.09. David used the line following function for all sessions of the SWMTP.

In the interview following the SWMTP David's mother discussed that she was pleased that David was switching independently and eager for David to transfer these skills to the classroom. She felt that it was hard to directly attribute participation in the SWMTP with positive changes in his behaviour such as increased eye contact, but she did feel that David demonstrated an increase in positive affect:

*"Few occasions when I have said to my husband 'oh Daniel is really happy today'. And he can be but, [has been a] few more times than usual."*

David's mother had also observed changes in his motor patterns:

*"Recently looking for toys and reaching around [his wheelchair] in the last couple of months. More use of his right arm".*

Sandra

Sandra was a 12 year old girl with spastic quadriplegia and dyskinetic CP. She was dependent on her parents and carers for all ADLs and attended a WA Department of Education Support School. She communicated 'yes' and 'no' through eye movements and was fed through a gastrostomy feeding tube. Switching had been trialled previously with Sandra, but due to her dyskinetic movements, her switch access was often unreliable. Two switches were trialled with Sandra, the most successful being a large plate switch, which was placed on her tray. Sandra made contact with this switch with her fingers, back of her hand or her wrist. Due to ill health Sandra was able to attend seven of the 16 SWMTP sessions.

Sandra's increased motivation to mobilise was evident through her high level of alertness and determination to overcome dysfunctional movement synergies. She self regulated her fatigue by taking regular rest breaks. Sandra understood cause and effect in relation to driving the Smart Wheelchair and she looked in the direction of movement at all times. Sandra used the line following function for all sessions of the SWMTP. During the first five SWMTP sessions, Sandra required stand-by assistance to activate the switch (see graph 2). In her last two sessions, the switch was changed to one with a larger surface area which assisted her to dampen her dyskinetic movements. Repetition facilitated intrinsic feedback for Sandra to control her movement synergies and energy expenditure. In session six Sandra began to independently switch (see graph 2). As described by Sandra's mother this represented an important milestone:

*"We have been trying to get Sandra to switch for years, she is 12 and we started when she was four. We haven't had much progress, because she really gets too frustrated and in the end she just gives up. Where as something like that she wants to do it because she wants to move forward... Sandra's [Teacher] saw Sandra in [the Smart Wheelchair] she said she just did so well, it was voluntary, she was accurate in her switching, she stopped when she wanted to stop, she obviously feels more comfortable."*

In the first session Sandra's total average score on the driving skills assessment was 0.63 compared to the last session where she scored 1.36. Sandra's improved switching abilities also had a positive impact on her performance at school. As her mother explained:

*"As far as school is concerned, they definitely see improvement."*

Following participation in the SWMTP Sandra's mother observed an increase in her daughter's confidence and affect:

*"She was really proud of herself because it was something she achieved on her own...It was almost like the penny dropped with her to physically be able to control the switch and that is a massive achievement for Sandra to do something like that...When they do something right, they become confident. It is nice to see when we mention something that she has achieved, she lights up and she thinks she is pretty good, it is so nice, because you don't get that very often...There are not many things that are available for these kids to make them feel good about themselves."*

Sandra's mother summarised the impact the SWMTP had on Sandra and her perceptions of the Smart Wheelchair as an intervention tool:

*"It would be really nice to have it ongoing, it would improve a lot of things in their life, it is an incentive, they do it on their own. They need something that they want to do independently. Everything gets done for them but this is something they can do on their own. It's a great thing, I'm really pleased that it is out there."*

### Blake

Blake was a five year old boy with spastic quadriplegia and epilepsy. He was dependent on his parents and carers for all ADLs and communicated with vocalisations and facial expressions. He attended conductive education classes at a WA Department of Education Support School. Blake had poor head control and was fed through a naso-gastric tube. He had previously been encouraged to switch, however his switching performance was unreliable. Due to ill health Blake attended 11 of the 16 SWMTP sessions

A large button switch was placed on Blake's tray, with the intention that he would reach forward with his left arm to activate the switch with his fingers. To begin with Blake required hand over hand prompting to press the switch, however he clearly understood the causal relationship between activating the switch and driving forward. After six sessions Blake was independently activating the switch to drive forward (see graph 3). Once Blake achieved this skill the switch was adapted from timed, where movement is set to a specific amount of time, to momentary, where Blake determined the amount of time spent moving by maintaining constant pressure on the switch. Blake's hand control gradually improved and he was capable of independently holding his hand on the switch to drive for a minimum of ten seconds (see graph 3). By the eleventh session Blake was able to stop on command with verbal prompting (see graph 3). In the first session Blake's total average score on the driving skills assessment was 0.18 compared to the last session where he scored 3.27. Blake progressed from the line following function to using the collision sensors.

One key improvement observed over the course of the SWMTP was Blake's ability to look in the direction of movement. For the first five sessions Blake held his head down and looked only at the switch and laterally out of the corner of his eye. With verbal prompting, Blake began to gradually lift his head to look in the direction of movement as well as to notice his environment. This was particularly apparent when Blake began driving outside. This change in physical context engaged Blake and facilitated an improvement in his performance. Blake looked in the direction of movement for the last three sessions (see graph 3).

In the post intervention interview Blake's mother described the process she felt her son undertook to establish the correct timing and sequencing of his movement synergies:

*"He was head up looking around for the first time... as opposed to the weeks before hand, where he was just looking down at the switch to know where it was, but it is as if that the message to the arm has become automated so he knows how to move his arm to reach the switch, he knows where*



*the switch is going to be, and now he has given himself stage two, I am now able to do that and look where I am going.”*

Following the SWTMP, Blake demonstrated skills he had previously not had the opportunity or motivation to develop:

*“Talking with [the therapist], we think he might be able to work on, not just cause and effect type activities on the computer but now scanning and choice..., which then translates to communication devices and more inclusion and accessibility to other people and being involved in that way. But that is a stage that he wasn’t ready for at all before, we just hadn’t put him in that category yet, but he seems to be more improved now.”*

Blake’s mother observed several psychosocial improvements following the SWMTP. She reported that Blake had demonstrated more initiative to attempt tasks, was more motivated to participate in activities, and was demonstrating increased positive affect. Blake was vocalising more and his mother reported he was communicating with new vocalisations. In addition, Blake’s use of his left arm had increased:

*“He reached out a bit more to play with a toy...or to knock down blocks. A little bit more use of arm and reaching movement...Huge [change in vocalisations], much more vocal and even different sounds...He is wanting to be part of a group’s activities vocally and that’s a difference...More initiative, willingness and some more enthusiasm for trying and motivation, rather than giving up.”*

Blake’s mother observed the motivational impact independent mobility had on her child:

*“It has come at the right time, because even emotionally and mentally he was at a giving up stage, we hadn’t done hardly any programs for a long time, so now we did this and it is as if he was given a chance to prove that he can do something new, he is happier, more vocal and more enthusiastic.”*

Pauline was a six year old girl with spastic diplegia involving both spasticity and dystonia. Pauline attended a main stream school and was capable of assisting her parents with some ADLs such as dressing and bathing. Pauline independently ate soft foods and could follow simple instructions as well as verbalise her needs. Pauline was a very social girl and was capable of basic communication in both English and Swedish. Due to ill health Pauline attended 11 of the 16 SWMTP sessions.

Pauline demonstrated poor hand control due to her tonal pattern and initially required a soft switch. Pauline began the SWMTP using the line follower function, then progressed to collision sensors, and finally was capable of driving without the use of sensors. As Pauline progressed she began to use three switches set on momentary, to manoeuvre forward, left and right. Through constant repetition and intrinsic feedback, Pauline developed the necessary postural control and movement synergies required to activate a flat button switch. Pauline's problem solving, motor planning, spatial understanding and bilateral coordination significantly improved from requiring verbal prompts to navigate and stop, to independently driving through doorways and turning corners (see graph 4). In the first session Pauline's total average score on the driving skills assessment was 1.90 compared to the last session where she scored 5.

Pauline consistently demonstrated positive affect whilst driving by laughing and smiling. Pauline continually vocalised her ability to drive by stating "*I can*" proudly. She also confirmed her independence by repeating frequently "*on my own*". In the last three SWMTP sessions Pauline began to incorporate imaginary play, stopping for pretend trucks to pass, and asking an imaginary person for directions. This demonstrated significant developmental progression in play.

Pauline's mother observed the positive impact the SWMTP had on her child's confidence, independence and initiative to perform tasks:

*“Because she sees she can do the driving on her own and she’s controlling that, I think she now realises that she can control a few things and is more willing to try to do that... She is more confident... that she can do things, amongst them thinking that she can tell me what to do while we are in the car, because she has been doing her driving lessons. Definitely more content to do things on her own. More wanting to try things on her own.”*

Pauline’s mother reported that she was previously reluctant for Pauline to use a PWC however, Pauline’s increased independence and positive affect were all factors facilitating her to change her point of view:

*“Personally, so excited to see her being independent, being able to do something herself, and able to control something herself in her environment that she can’t really always do otherwise. And the excitement, she has been so happy doing it and absolutely loving it...I’ve always been very hesitant about a motorised wheelchair for lots of different reasons, but seeing her do this and that she is able to do it, I think has changed my view of the whole thing.”*

As a result of the SWMTP Pauline’s therapist and family are applying for funding for a PWC, a piece of equipment her family had not previously considered.

## **Discussion**

The aim of this study was to describe the impact of a mobility training program using the Smart Wheelchair on the driving skills and psychosocial outcomes of children with CP. Following the SWMTP three out of four children gained independence using the Smart Wheelchair in at least three driving skills or more, whilst one child was competent with verbal prompts. Three out of four mothers reported positive changes in their child’s confidence, motivation and affect. Although the evidence is descriptive in nature, these findings suggest that the Smart Wheelchair has the potential to improve the driving skills and psychosocial outcomes of children with CP, who have previously been excluded from powered mobility training.

Findings from this study highlighted the need to look beyond a child's limitations in order to uncover potential abilities. The Smart Wheelchair was a useful tool for uncovering skills and abilities previously unrecognised in all of the children. The importance of powered mobility as a therapeutic tool has been discussed by therapists working with children with multiple and complex disabilities [41,42]. This approach is based on the premise that sensory stimulation and change in body positions resulting from powered mobility can raise an individual's alertness, enhancing their ability to understand simple causal relationships [41]. Findings from the present study suggest that powered mobility not only has the potential to help develop understanding of causal relationships, but to increase motor performance, postural control and influence positive psychosocial changes.

The SWMTP was underpinned by motor learning theory [19]. Previously, children in this study were believed to lack the pre-requisite skills required for powered mobility. Application of this theory allowed the children to receive constant intrinsic and extrinsic feedback through repetition and practice, consequently facilitating skill acquisition [19]. Children were able to reinforce the development of learnt skills on consecutive days and, repetition and practice were key factors in the acquisition of driving skills in all four children. This is in line with findings which suggest repetition over time is essential for skill development in children with multiple and complex disabilities [17,41]. This study also confirms that removing pre-determined criteria and rigid protocols when providing powered mobility training, enhances the development of skill learning specific to each individual child [20]. These findings support the idea that the emphasis in therapy should be placed on the therapist as a responsive partner who can elicit new learning through providing responsive feedback rather than commanding instructions [17,20]. Research suggests that this method reduces the child's dependency on adults and encourages children to take more initiative for their own learning [43].

Parents perceived that the SWMTP facilitated an increase in their child's motivation, affect, and initiative to participate in play and therapeutic activities. These changes in psychosocial outcomes are important

achievements for children with multiple and complex disabilities as they have fewer opportunities for contingency learning and often develop learned helplessness as a secondary effect [9,44]. For these reasons it is imperative that children with multiple and complex disabilities are provided with as many opportunities as possible to explore their environment. The Smart Wheelchair has the potential to break this cycle of learnt helplessness. The findings of this study are consistent with findings from a systematic literature review of powered mobility interventions for children with CP [45]. Five studies in the review evaluating psychosocial outcomes, found independent powered mobility promoted increased social interaction, increased motivation to move and interact with the environment, and increased independence [41,46-49].

The development of new assistive technologies for individuals with disabilities has increased over the past three decades [50,51]. New models of wheelchairs such as the CALL Centre Smart Wheelchair and the Collaborative Wheelchair Assistant have been developed using advanced technologies and robotics [22,52]. Current evidence suggests that technologically advanced wheelchairs can increase driving skills in adults and children with disabilities [10,52,53]. However, there is a paucity of evidence to describe how effective these new technologies are for children with CP. This study described how the Smart Wheelchair can be used as a safe therapeutic tool for children with CP. The Smart Wheelchair allows the therapist to tailor the level of driver control, to suit the child's needs. As a child's skills progress, the Smart Wheelchair can be adapted to complement and expand their skills [10]. During the SWMTP it became apparent that this capability was crucial in allowing children with multiple and complex disabilities the opportunity to explore their abilities. The Smart Wheelchair appeared to be a reliable and efficient therapeutic tool, however, there is a clear need for future research to further explore the effectiveness of the Smart Wheelchair.

Occupational therapists are concerned with enabling the achievement of occupational performance for all individuals [15]. When considering powered mobility in the context of occupational performance, Smart

Wheelchairs are clearly a valuable intervention tool. Independent mobility has the ability to enhance occupational performance and participation in valued life roles, enhancing feelings of self efficacy and competence [54]. Children with multiple and complex disabilities are generally dependent for all ADLs and instrumental ADLs. The Smart Wheelchair has the capacity to provide these children with an activity they can control independently. There is an increased demand for clinical interventions such as the Smart Wheelchair as there are growing numbers of children with CP. Wheelchairs using advanced technology are expensive and, purchase of an inappropriate PWC can lead to technology abandonment [55]. The Smart Wheelchair allows for a complete assessment of abilities and helps to ensure that the most beneficial equipment is purchased, reducing the financial burden on families and service providers. However, an evidence base supporting the use of Smart Wheelchairs with children with CP must first be established in order for occupational therapists to support evidence based practice.

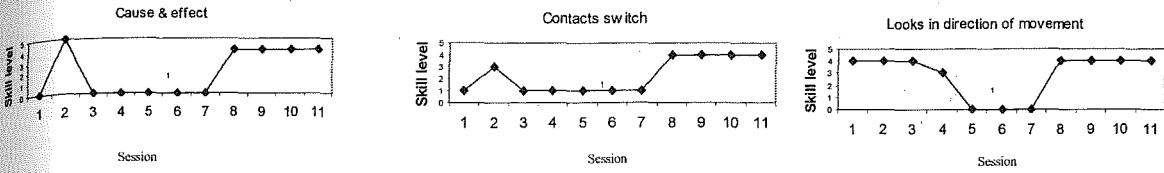
These findings must be interpreted with caution due to the following limitations. The small number of participants and the short duration of the SWMTP limits the transferability of the research findings [39]. Internal validity was weakened due to the effects of extraneous factors such as therapies received outside of the SWMTP and school programs [26]. The broad nature of the intervention protocol permitted variations in therapy for each child, limiting the intervention fidelity [56]. This research was descriptive in nature, and for this reason a causal relationship between the SWMTP and improvements in driving skills and psychosocial outcomes cannot be assumed [26]. Children with multiple and complex disabilities often have high levels of co morbidity and ill health. All four children were unwell several times during the SWMTP disrupting the continuity of the intervention however, this was expected when conducting clinical research with children of this nature.

## **Conclusion**

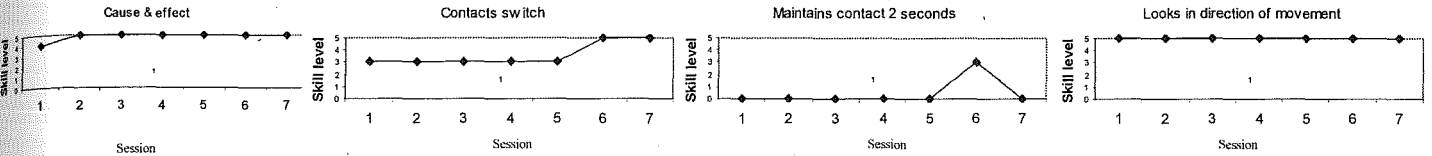
This study described how the SWMTP improved driving skills and impacted positively on psychosocial outcomes in four children with CP. The Smart Wheelchair has the ability to uncover learning potentials

and facilitate the recognition of abilities in children with CP. Advances in technology are providing more individuals access to mobility opportunities previously inaccessible. These technologies have the potential to maximise the quality of life and independence of children with CP. Clinical research involving the clinical application of the Smart Wheelchair and its therapeutic benefits should be conducted. There is also a need for future, more rigorous research to determine causal relationships between the Smart Wheelchair and mobility outcomes. This study is descriptive in nature however, these findings contribute valuable knowledge in the field of powered mobility for children previously excluded from access to independent mobility.

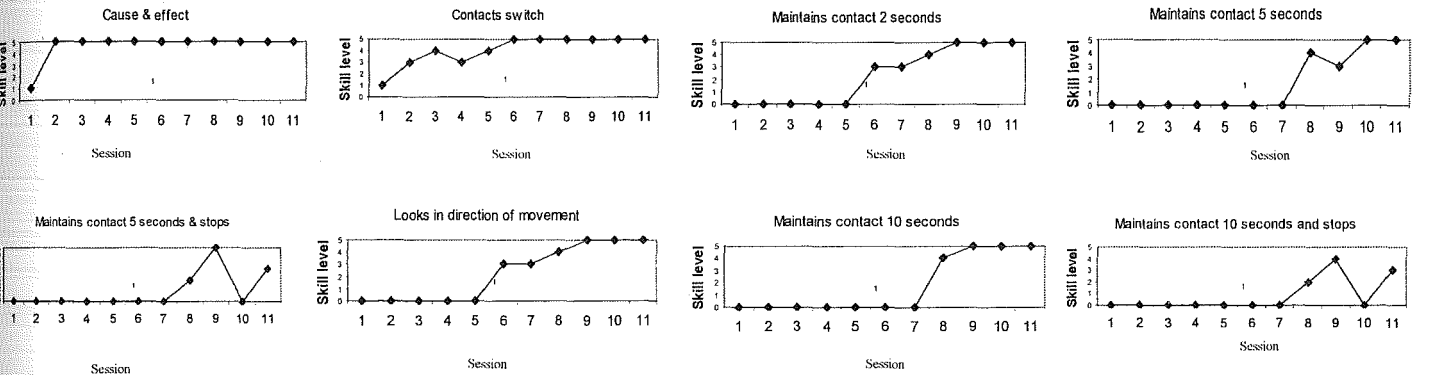
Graph 1. David



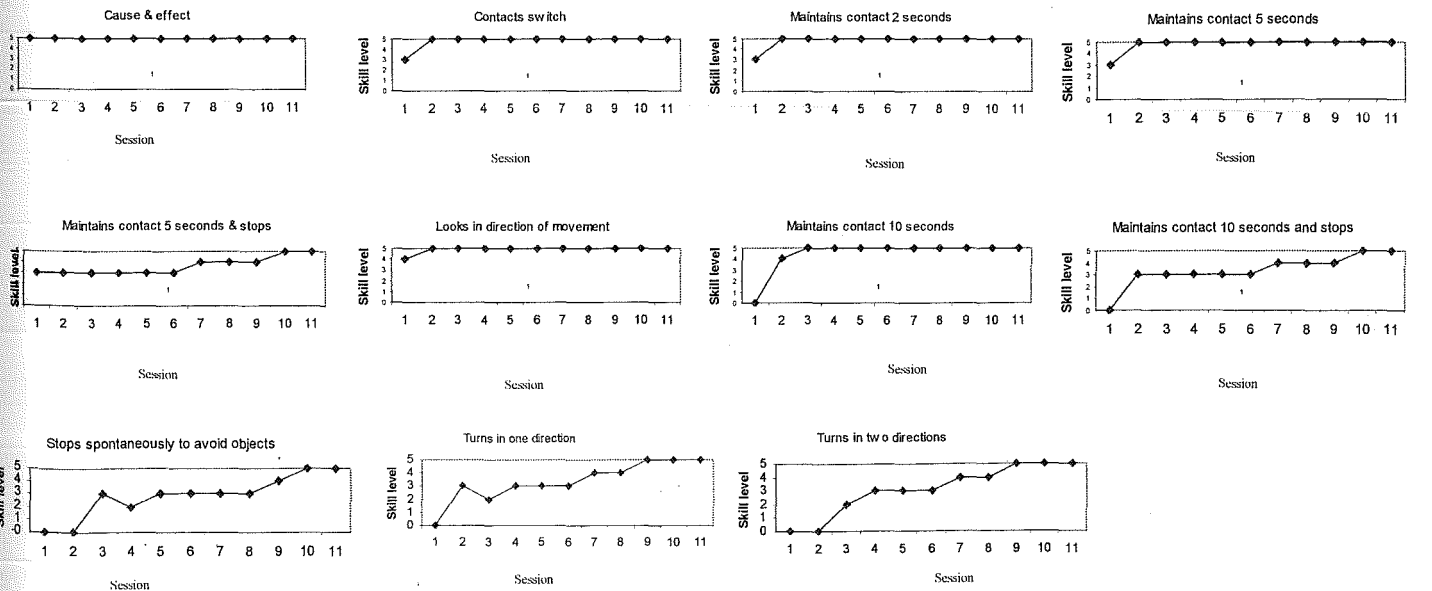
Graph 2. Sandra



Graph 3. Blake



Graph 4. Pauline





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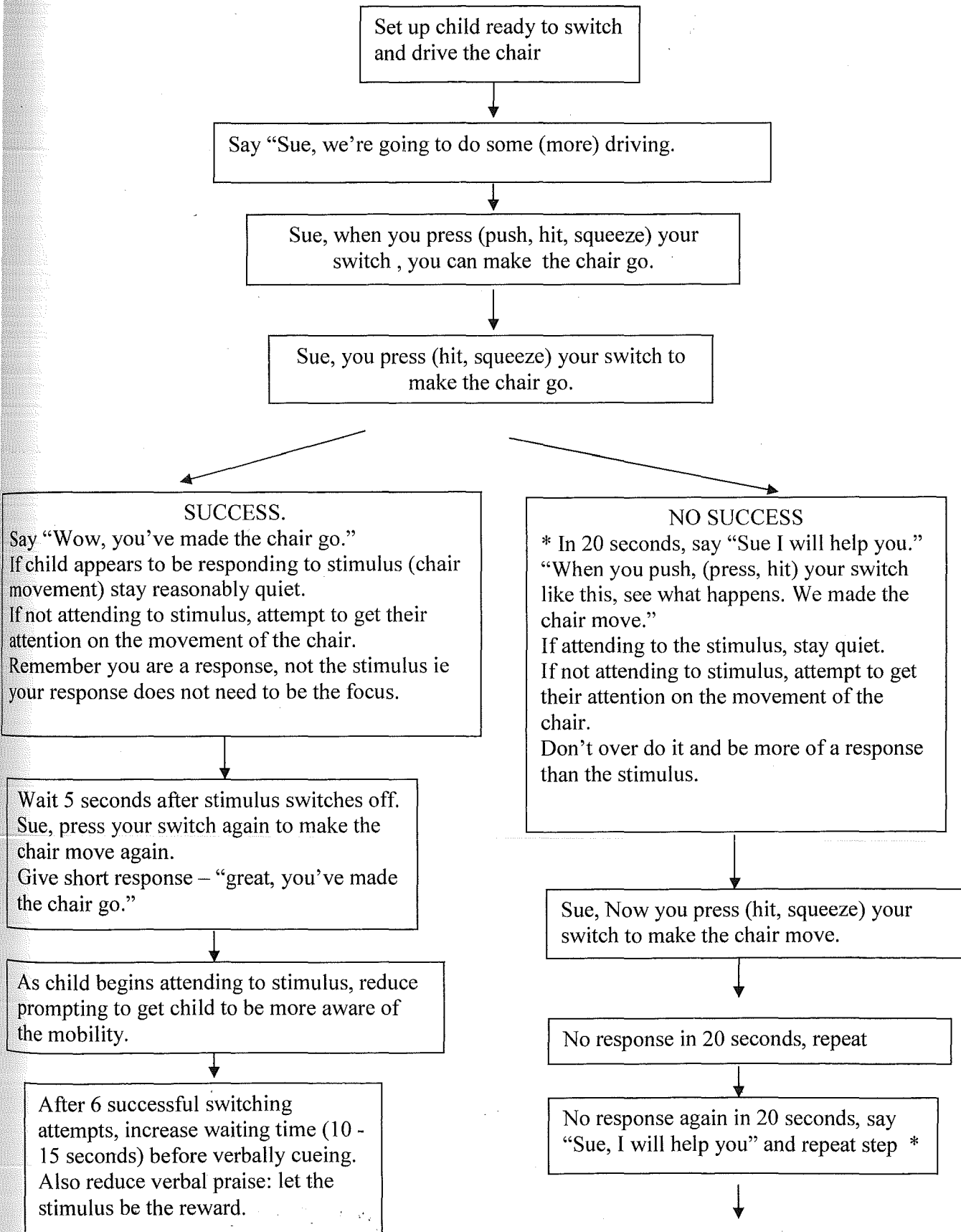
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**Appendix A**  
**Intervention protocol for weekly sessions**



After 6 more successful switching attempts, increase waiting time to 30 seconds before verbally cueing. Reduce verbal response to one/two words – “wow”, “great”, “good switching”, “you’re moving”.

If success reduces go back to sequence where child was successful and double number of times of success before moving on again.

Reduce verbal cues as success is maintained. “Sue, make the chair go”. Don’t just say “press your switch – this does not help child to learn or reinforce cause and effect.

Provide verbal feedback, but allow the switched stimulus to provide the feedback.

Monitor child’s responses – child may work hard for 15 minutes then be tired. Note this and allow for altered levels of response.

Repeat procedure; give assistance to switch a total of 5 times

If no response, repeat procedure \*  
 Increase waiting time to 40 seconds.  
 Reduce physical prompt if possible eg push from elbow, finger on hand.  
 Add some excitement to your voice.

If no success repeat up to 5 times.

If child fails to succeed at all at switching

- Have a rest for 5-10 minutes and try again
- Is child well, thirsty, too tired etc?
- Consider a different method of switching.

## Intervention Protocol

### Weekly Sessions

Each session was 45 minutes in duration. This was shortened or modified if the children showed signs of fatigue or distress.

### Chair Settings

The following Smart Wheelchair settings were used during the program to enhance the driver's abilities:

- Line following
- Collision sensors
- Driver control

### Indoor Activities

Basic mobility sessions included the following meaningful and fun activities:

- Driving through a streamer curtain
- Driving through a sound beam
- Driving past mirrors
- Driving on a mat switch connected to a switch adapted toy

### Outdoor Activities

Functional mobility sessions included the following meaningful and fun activities:

- Driving into the classroom
- Taking a message to the principal's office
- Visiting the library
- Driving around the playground



**Appendix B**

**Driving Skills Assessment**

Assessment Scale:

- 0 – Task not attempted
- 1 – Maximal hands on assistance of switch with verbal cuing
- 2 – Minimal hands on assistance of switch with verbal cuing
- 3 – Direct stand-by guarding with verbal cuing
- 4 – Verbal cuing only
- 5 – Age appropriate supervision

<b>Basic Mobility Skills</b>	<b>1<sup>st</sup> Session</b>	<b>2<sup>nd</sup> Session</b>	<b>3<sup>rd</sup> Session</b>	<b>4<sup>th</sup> Session</b>	<b>5<sup>th</sup> Session</b>
Basic cause and effect association					
Contacts switch to engage wheelchair in motion					
Maintains contact with the switch for a minimum of 2 seconds					
Maintains contact with the switch for a minimum of 5 seconds					
Maintains contact with the switch for a minimum of 5 seconds and stops on command					
Looks in the direction of movement					
Maintains contact with switch for 10 seconds					
Maintains contact with switch for 10 seconds and stops on command					
Stops spontaneously to avoid stationary objects					
Switches to turn in one direction					
Switches to turn in two directions					

Modified from Powered Mobility Program developed by Furumasu, Guertette & Tefft (1996)

## Appendix C

### Semi Structured Interview Guide

Today we are going to discuss the impact of the mobility training program on your child, but before we start could you tell me a little bit about your son/daughter?

- Can you tell me about any changes you have noticed in your child's behaviour over the past eight weeks?

Probe:

- At home?
- At school?
- Self stimulating behaviour?

- Can you tell me about any changes you have noticed in your child's communication with others?

Probe:

- Family?
- School friends?

- Can you tell me about any changes you have noticed in your child's initiative to do things?

Probe:

- Socialise?
- Mobilise?
- Play?

- What are the positive and negative experiences your child has had as a result of the mobility training program?
- Is there anything else you would like to share as part of this interview?

**Appendix D: Description of included studies**

Authors, year of publication	Design and sample	Intervention details	Outcome measures	Results	Methodological quality
Butler, Okamoto, McKay (1983)	Single case design (n = 9) children	<ul style="list-style-type: none"> <li>Children were provided with powered wheelchairs and learned to drive at home under parent supervision.</li> <li>Intervention duration = 6 weeks</li> </ul>	<p><b>Driving skills</b></p> <ul style="list-style-type: none"> <li>Seven skill driving checklist</li> <li>Video recordings</li> </ul> <p><b>Parent's perception</b></p> <ul style="list-style-type: none"> <li>Parent interview</li> </ul>	<p><b>Driving skills</b></p> <p>8/9 children gained independent use of their power wheelchair (PWC).</p> <p><b>Parent's perception</b></p> <p>Parents noticed a positive effect on their child's social, emotional and intellectual behaviours, and an increased motivation in other forms of movement.</p>	<p>Limited quality (score = 6/22, 27%)</p> <p>Level IV evidence</p> <p>Conclusion was limited because of small sample size, no rigorous randomisation, and no blinding.</p>
Butler, Okamoto, McKay (1984)	Single case design (n = 13) children	<ul style="list-style-type: none"> <li>Children were provided with PWCs and learned to drive at home under parent supervision.</li> <li>Intervention duration = 1 month</li> </ul>	<p><b>Driving skills</b></p> <ul style="list-style-type: none"> <li>Parents recorded their child's experience with the PWC including hours driving, time spent in the PWC and behaviours.</li> <li>Seven skill driving checklist</li> </ul>	<p><b>Driving skills</b></p> <p>12/13 children learnt to competently drive a PWC in an average of 16.3 days with a median of 14 days.</p> <p>Children learnt 4-5 driving skills within a 1-5 day period.</p> <p>Cumulative time of wheelchair driving averaged 8.1 hours with a median of 6.0 hours (range 1.7-26.1 hours). The cumulative time spent sitting in the wheelchair averaged 34.4 hours with a median of 20 hours (range 6.6-168 hours).</p>	<p>Adequate quality (score = 11/22, 50%)</p> <p>Level IV evidence</p> <p>Conclusion was limited because of small sample size, no rigorous randomisation, and no blinding.</p>
Butler, (1986)	Single subject time series design with multiple baselines. (n = 6) children	<ul style="list-style-type: none"> <li>Each child was provided with a PWC and learnt to use it to a level of proficiency (defined by 7 <i>a priori</i> criteria).</li> <li>Intervention duration = 3 weeks.</li> </ul>	<p><b>Self initiated interaction with increased change in location.</b></p> <ul style="list-style-type: none"> <li>Video footage</li> </ul> <p><b>Self initiated interaction with objects</b></p> <ul style="list-style-type: none"> <li>Video footage</li> </ul> <p><b>Self initiated interaction in communication</b></p> <ul style="list-style-type: none"> <li>Video footage</li> </ul>	<p><b>Self initiated interaction with increased change in location</b></p> <p>Clinically and statistically significant for all participants. T = 3.57, (p&lt;0.05)</p> <p><b>Self initiated interaction with objects</b></p> <p>3 children increased in their self initiated interaction with objects. No consistent changes were recorded for the group. Variability in changes meant the results were not statistically reliable. T = 0.86, (p&lt;0.21)</p> <p><b>Self initiated interaction in communication</b></p> <p>3 children increased in self initiated interaction in communication. No consistent changes were recorded for the group. Variability in changes means the results were not statistically reliable. T = 0.80, (p&lt;0.22)</p>	<p>Adequate quality (score = 12/22, 54.5%)</p> <p>Level IV evidence</p> <p>Conclusion was limited because of small sample size, no rigorous randomisation, and no blinding.</p>
Bottos, Bolcati, Scuto, Ruggeri,	Case history survey design. (n = 29) children, 4 participants	<ul style="list-style-type: none"> <li>Initial no treatment period of 6-8 months (with pre and post assessment).</li> <li>6-8 month treatment</li> </ul>	<p><b>Impairment</b></p> <ul style="list-style-type: none"> <li>Performance IQ score of the Leiter International</li> </ul>	<p><b>Impairment</b></p> <p>Relationship between driving skills and Performance IQ score of the Leiter International Performance Scale or the Verbal IQ score of the</p>	<p>Strong quality (score = 19/22, 86%)</p> <p>Level IV evidence</p>

<p>Feliciangeli, (2001)</p>	<p>dropped out.</p> <ul style="list-style-type: none"> <li>Data for achievement/non achievement of driving competence (n=27)</li> <li>Data for influence of PWC provision on outcome indexes (n=25)</li> </ul>	<p>period (PWC provision)</p>	<ul style="list-style-type: none"> <li>Performance Scale. Verbal IQ score of the Peabody Developmental Verbal Scale.</li> <li><b>Functional Limitation/Activity</b></li> <li>Furumasa's Driving Test</li> <li>Gross Motor Functional Measure</li> <li>Canadian Occupational Performance Measure</li> <li>Impact of Childhood Illness Scale</li> <li><b>Parental perceptions and acceptance</b></li> <li>Parent interview</li> </ul>	<p>Peabody Developmental Verbal Scale was not statistically significant.  <b>Functional Limitation/Activity</b>                  Significant change (<math>p &lt; 0.01</math>), 21/27 children were competent driving a PWC.                  Relationship between Gross Motor and Functional Measure and driving skills was not statistically significant.                  Significant change between 2<sup>nd</sup> and 3<sup>rd</sup> assessment scores on the Canadian Occupational Performance measure (<math>p &lt; 0.00001</math>).  <b>Disability/Participation</b>                  No significant change (<math>p = 0.027</math>) on the Impact of Childhood Illness Scale.  <b>Parental perceptions and acceptance</b>                  21/25 parents were not in favour of PWC provision when the study started. After the study 23/25 parents expressed positive feelings about PWC provision.                  25/25 parents reported increase independence in their child.                  23/25 children expressed positive reactions from the beginning of the study, and did not change following the intervention.</p>	<p>Conclusion was limited because of small sample size, no rigorous randomisation, and no blinding.</p>
<p>Deitz, Swinth, White, (2002)</p>	<p>Single subject withdrawal design. (n = 2) children</p>	<ul style="list-style-type: none"> <li>Powered mobility training sessions on a powered riding toy in child's school environment. Intervention conducted by an occupational therapist and a researcher.</li> <li>Intervention duration = 14 weeks</li> </ul>	<ul style="list-style-type: none"> <li><b>Self initiative movement</b></li> <li>Video footage</li> <li>Manual counter (used on one participant only).</li> <li><b>Contact with others</b></li> <li>Partial interval video recording.</li> <li><b>Affect</b></li> <li>Momentary time sampling using video footage.</li> <li><b>Practicality of the powered riding toy</b></li> <li>Researchers experiences and interviews with</li> </ul>	<p><b>Self initiative movement</b>                  Increase in number of self initiated movements. Participant 1 increased from 44 (baseline stage) to 87 (intervention stage) and participant 2 increased from 28 (baseline stage) to 65 (intervention stage).  <b>Contact with others</b>                  Children made more positive contact with participant 2 during the intervention stage, and less positive contact with participant 1 during the intervention stage.                  Adults initiated more negative contact with participant 2 during the intervention stage and more positive contacts with participant 1 during intervention stage.                  Participant 2 had less positive initiations with</p>	<p>Adequate quality (score = 16/24, 66 %)                  Level IV evidence                  Conclusion was limited because of small sample size, no rigorous randomisation, and no blinding.</p>

			<p>school staff and one parent.</p>	<p>adults during intervention stage and participant 1 had more positive initiations with others during intervention stage.</p> <p><b>Affect</b></p> <p>No clear impact on the amount of positive or negative affect could be determined.</p> <p><b>Practicality of the powered riding toy</b></p> <p>Looks like a toy, gains children's interest, easy to adapt, low cost, useful evaluation and early training tool and adjustable speed are all positive aspects.</p> <p>Negative aspects include too loud, challenged by rough surfaces, impractical in small areas, and breaks down.</p>	
<p>Hasdai, Jessel, Weiss, (1998)</p>	<p>Cohort design (n = 22) children and young adults</p>	<ul style="list-style-type: none"> <li>Participants were divided into two groups, those with experience driving a PWC and those with no experience.</li> <li>After a driving assessment with a PWC the inexperienced drivers were trained on a joystick-controlled computer game in which they navigated mazes.</li> <li>Both groups driving skills were evaluated using a PWC.</li> </ul>	<p><b>Driving skills</b></p> <ul style="list-style-type: none"> <li>Functional evaluation rating scale</li> <li>Simulation program</li> </ul>	<p><b>Driving skills</b></p> <p>Significant improvement in driving performance for intervention group (p&lt;0.01)</p> <p>Scores of the inexperienced PWC users were lower than the experienced PWC users (p&lt;0.01)</p>	<p>Adequate quality (score = 15/26, 57.6%)</p> <p>Level III evidence</p> <p>Conclusion was limited because of small sample size, no rigorous randomisation, and no blinding.</p>
<p>Nilsson, Nyberg, (2003)</p>	<p>Case study design (n = 2) children</p>	<ul style="list-style-type: none"> <li>12 month powered mobility training program.</li> <li>3-4 x training sessions per week in a clinic setting for 4 months. Therapist conducted training.</li> <li>Training transferred to the children's homes for 8 months. Parent's and assistants conducted the training.</li> </ul>	<p><b>Participant behaviour</b></p> <ul style="list-style-type: none"> <li>Video recordings</li> <li>Field notes</li> <li>In depth parent interviews</li> </ul>	<p><b>Participant behaviour</b></p> <p>Increased ability to react to external stimuli.</p> <p>Increased development of initiative and exploratory behaviours.</p> <p>Increase in awakens and alertness.</p> <p>Encouragement of simple cause and effect relationships.</p> <p>Increased use of child's arms and hands.</p>	<p>Strong quality (score = 17/20, 85%)</p> <p>Level IV evidence</p> <p>Conclusion was limited because of small sample size.</p>

**Abbreviations**

PWC = power wheelchair

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$$\frac{6l + 5h + q}{3n + 3yz^2}$$

But:  $a/b + c/d + a/d$

$$P = (a^2 - b^2)(c^2 + d^2)$$

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Journal article:

[1] Steiner U, Klein J, Eiser E, Budkowski A, Fetters LJ. Complete wetting from polymer mixtures. *Science* 1992;258:1122-9.

Book chapter:

[2] Kuret JA, Murad F. Adenohypophyseal hormones and related substances. In: Gilman AG, Rall TW, Nies AS, Taylor P, editors. *The pharmacological basis of therapeutics*. 8th ed. New York: Pergamon; 1990. p 1334-60.

Conference proceedings:

[3] Irvin AD, Cunningham MP, Young AS, editors. *Advances in the control of Theileriosis*. International Conference held at the International Laboratory for Research on Animal Diseases; 1981 Feb 9-13; Nairobi. Boston: Martinus Nijhoff Publishers; 1981. 427 p.

Dissertations or Thesis:

[4] Mangie ED. *A comparative study of the perceptions of illness in New Kingdom Egypt and Mesopotamia of the early first millennium* [dissertation]. Akron (OH): University of Akron; 1991. 160 p. Available from: University Microfilms, Ann Arbor MI; AAG9203425.

Journal article on internet:

[5] Loker WM. "Campesinos" and the crisis of modernization in Latin America. *Jour of Pol Ecol* [serial online] 1996; 3(1). Available: [http://www.library.arizona.edu/ej/jpe/volume\\_3/ascii-lokeriso.txt](http://www.library.arizona.edu/ej/jpe/volume_3/ascii-lokeriso.txt) via the INTERNET. Accessed 1996 Aug 11.

Webpage:

[6] *British Medical Journal* [Internet]. Stanford, CA: Stanford Univ; 2004 July 10 - [cited 2004 Aug 12]; Available from: <http://bmj.bmjournals.com/>

Internet databases:

[7] *Prevention News Update Database* [Internet]. Rockville (MD): Centers for Disease Control and Prevention (US), National Prevention Information Network. 1988 Jun - [cited 2001 Apr 12]. Available from: <http://www.cdcnpin.org/db/public/dnmain.htm>

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