

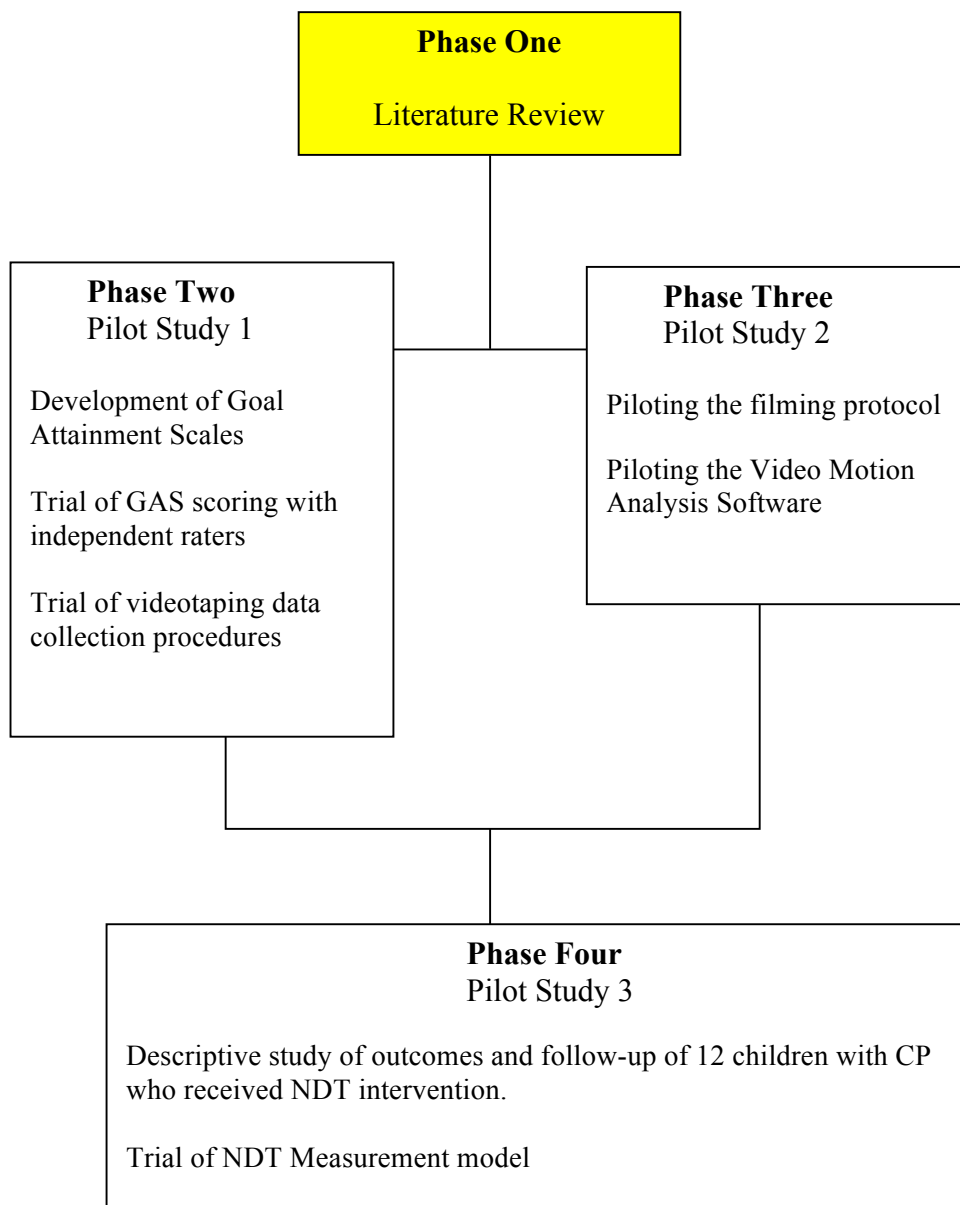
# CHAPTER TWO

## Phase One - Literature Review

### 2.1 INTRODUCTION

This literature review in phase one of the study (Figure 2.1) addresses the major variables contained in the overall research question of this study which was: *What is the impact of NDT on the functional outcomes of children with cerebral palsy as measured by their performance in selected daily living tasks?* Contained in the review is current evidence of the impact of Neuro-Developmental Treatment (NDT) on children's participation and independence in daily tasks. Daily tasks include self-care, mobility, hands skills, communication, educational and vocational skills, leisure pursuits and play (Howle, 2002; World Health Organisation, 2001). The epidemiology and classification of the cerebral palsies are briefly reviewed. Then, following a short introduction to the 'equivocal evidence base' for NDT, the current NDT theoretical model and operational definitions are discussed. Current practices of NDT are contrasted with studies in which earlier NDT practice ideas were used. Evidence related to frequency and intensity of NDT sessions and studies, showing outcomes following application of current NDT approaches, are also reviewed. These sections lead into a review of the research methodologies used to measure outcomes. Two measures, Goal Attainment Scaling (GAS; Kiresuk, Smith, & Cardillo, 1994) and 'onscreen measures' from video analysis, have been targeted for particular review to support the methods used in later stages of this research. Difficulties experienced by researchers in carrying out NDT efficacy studies are reviewed using some

examples from earlier research which produced equivocal or negative outcomes for NDT, leading to suggestions for more appropriate methodology and outcome measures. Finally, families' perceptions of NDT outcomes will be reported.



**Figure 2.1:** Visual representation of the four phases of the study, with Phase One highlighted.

## **2.2 SEARCH STRATEGY**

An electronic search of literature on the efficacy of NDT was conducted using the following data bases: Web of Knowledge, Current Contents Connect, Medline, Ovid, Cinahl, Embase, Medline, PubMed, PsycINFO, Proquest and Proquest Digital Dissertations, Journals at Ovid, Ovid Full Text, Cochrane Reviews, PEDro, OT Seeker and Science Direct (Seminars in Paediatric Neurology) and Wiley Interscience. Articles were also sourced through scanning reference lists.

Inclusion criteria were broad. All papers reporting NDT efficacy studies published between 2000 and 2010 and written in English were included. A number of articles were also sourced from the 1990s and the 1980s. The aim was to compare results related to earlier NDT theory with the more current research outcomes. Papers reporting on Goal Attainment Scaling (GAS; Kiresuk, Smith, & Cardillo, 1994) and video recorded outcome measures were included. The search extended broadly to cerebral palsy, NDT theory and practice, and the treatment outcomes of other 'related' treatment frameworks. Papers prior to 1980 and NDT treatment for adults were excluded.

## **2.3 CEREBRAL PALSY (CP): EPIDEMIOLOGY AND CLASSIFICATION**

Cerebral Palsy (CP) is identified as the most common cause of severe physical disability in children. Its prevalence rate is approximately 2-2.5/1000 live births [Koman, Smith, & Shilt (2004) and Lin (2003), cited in Steenbergen & Gordon, (2006)]. There are 500 – 600 new cases of cerebral palsy each year in Australia and 10,000 each year in the United States (Boyd, 2006; Eskew & Dawson, 2001).

An estimated 20,000 Australians have CP (CPAWA, 2005). CP begins early in childhood and it persists through life (Rosenbaum, Paneth, Leviton, Goldstein, & Bax, 2006). Possible causal pathways to CP relate to prenatal, perinatal and postnatal periods (Stanley, Blair, & Alberman, 2000). CP may result from multiple risk factors or the cause may be unknown (Rosenbaum et al., 2007). Cortical malformations are considered a majority cause in the aetiology of CP (Leventer, 2004), together with vascular lesions (Gorter, 2006). Leventer (2004) identified prematurity as the second largest causative factor.

The incidence of CP has continued to increase due to the improved survival rates of preterm neonates as a result of contemporary care in Neonatal Intensive Care Units (NICU's), such as assisted ventilation. Neonatal death rates (<1500g) have reduced while cerebral palsy rates have increased in the survivors (Blair & Watson, 2006; Stanley, 2002). There is also increasing incidence of CP in multiple births (Blair & Watson, 2006). The numbers of individuals with CP and its continuing incidence means that families and service providers continue to seek therapy intervention for children with cerebral palsy.

A current definition of cerebral palsy describes “a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing foetal or infant brain” (Rosenbaum et al., 2007, p. 2). The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behaviour, by epilepsy and by secondary musculoskeletal problems (Rosenbaum et al., 2007). Although considered permanent, aspects of CP are also ‘often changing’, although non-progressive (Himmerlmann, Beckung,

Hagberg, & Uvebrant, 2006, p.2). For example, Blair and Watson (2006) refer to clinical changes seen in motor development, and in muscles and tendons affected by the primary impairments. Similarly, aspects of fine motor skills and associated postural control may change with growth, and activity patterns needed during occupational performance (Boyd, Morris, & Graham, 2001). The aim of effective intervention as it applies over time, should be relevant in addressing a child's needs and would change in response to the child's evolving needs: such as, for example, deterioration in the available range of soft tissue (Howle, 2002).

Classification of CP has continued to be modified in response to identification of multiple clinical features and through neuro-imaging (Rosenbaum et al., 2007). Gorter (2006) classified CP in the following heterogeneous groups: spastic (88% of children with CP), dyskinetic (7%), ataxic (3%) and unidentifiable (2%). He also refers to hypotonia, dystonias, and presentations combining classifications of the above groups. Clear description of the motor disorder, the functional effects and distribution among body regions (such as upper and or lower extremities and unilateral or bilateral involvement) are also important in classification (Rosenbaum et al., 2007). Odman and Oberg (2005, p. 1) refer to "the heterogeneity of CP (which) comprises a wide range of functional problems and gives rise to a variety of needs of children and their families". For example, children with CP experience limitations to participation in active physical activities. There may be associated impacts upon their capacity to engage in desired levels of socialization, and upon long-term health. In adolescence, many are still not able to perform various self-care and mobility tasks independently (Imms, Reilly, Carlin, & Dodd, 2008; Palisano, Copeland, & Galuppi, 2007). Relationships among family members

change as adolescents make the transition from dependence upon family members for intimate care needs to ‘professional’ personal care assistants.

The heterogeneous nature of CP, and the fact that it is a non-progressive disorder with the potential to change has posed methodological difficulties for researchers who have attempted to determine the efficacy of intervention related to functional outcomes, irrespective of the classification of CP.

## **2.4 AN INTRODUCTION TO THE EVIDENCE BASE FOR NEURO-DEVELOPMENTAL TREATMENT (NDT)**

NDT can be briefly described as a ‘hands-on’ approach used in the treatment of children with central nervous system insults. NDT aims to help children achieve their highest functional participation in daily skills, using their most efficient movements (NDTA, 2006; Stamer, 2006b). It is “an approach used to assess and to assist children with CP to perform functional tasks sooner, better and with minimal negative effect on future functional abilities” (Sharkey, Banaitis, Guiffrida, & Mullens, 2002, p. 2). NDT is described as an ecological approach; that is, a family centred intervention driven by the individual goals of parents and children, and in consideration of children’s individual strengths and their desired levels of participation in their natural environments, such as at home and in the community (Chapparo, 2009). NDT advocates engagement of children’s motivation through playful treatment environments as a milieu for intervention (Blanche, 1999; Bly, 1991; Davis, 2004; King, 2002; Palisano, Snider, & Orlin, 2004). The NDT framework is cited as the most commonly used approach for children with CP, despite the number of studies that have been unable to prove its

efficacy (Bar-Haim, Harries, Belokopytov, Frank, Copeliovitch, Kaplanski, & Lahat, 2006; Berry & Ryan, 2002; Jeanson, 2005; King, 1997).

In order to confidently support interventions that purport to improve the level of independence of children with CP, practitioners, families and funding bodies must first be able to make informed, judicious and accurate decisions about evidence-based ‘best practice’ (Barry, 2001; Damiano, 2007; Fritz & Wainner, 2001; Howle, 2008; Ottenbacher, 2001; Palisano, Snider, & Orlin, 2004; VanSant, 2008). NDT is one such intervention mode that is increasingly being required to demonstrate evidence of effectiveness.

Howle (2008) suggests that for NDT, a “logical first step in evidence-based decision making is identifying the theoretical framework that ...guides our decisions for including or excluding particular intervention strategies” (p.203). She further cautions that although “we may hypothesize, as neuro-developmental treatment (NDT) therapists do, that addressing posture and movement impairments within a systems perspective of motor control<sup>1</sup> is an effective way to change a client’s function” (p.203), evidence is required to support this fundamental assumption. Current NDT is focused on the individual achievement of functional goals. Howle (2005) emphasizes the importance of being able to measure the change in function following NDT, and further, to link functional change to change in the related underlying motor and body systems. Howle (2005) cites Brown and Burns (2001) in advocating the use of carefully recorded observations of both *function* and *motor systems* that can be used for research purposes to determine

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<sup>1</sup> The ‘systems perspective of motor control’ with emphasis on the body systems and the environment in treatment strategies is described in Howle, 2002.

intervention effectiveness. One aim of this current research targeted the development of a measurement model that would have the capacity to simultaneously measure both function and motor aspects of intervention effectiveness.

While it is proposed that clinical decision making for children with cerebral palsy be based on convincing scientific evidence (Barry, 2001; Campbell, 1989), only a relatively small number of studies have investigated the efficacy of NDT, with the overall consensus that evidence of benefit has not been established (Anttila, Suoranta, Malmivaara, Makela, & Autti-Ramo, 2008; Fetters & Kluzik, 1996; Sheppard, Mudie, & Froude, 2007; Siebes, Wijnroks, & Vermeer, 2002).

Similarly, there is currently no empirical consensus showing that NDT is more valuable than other therapies (Butler & Darrah, 2001; Howle, 2002; Tsorlakidis, Evaggelinou, & Tsorbatzoudis, 2004). It is upon this equivocal body of evidence that the contemporary model of NDT will be reviewed.

Two theoretical perspectives have been selected to shape this research and are described in the following sections of this chapter. First, contemporary NDT frameworks will be used to demonstrate the premise upon which current intervention strategies have been developed. Second, the Occupational Performance Model (Australia; Chapparo & Ranka, 1997) has been employed to further illustrate the proposed links between cerebral palsy, motor capacities and everyday functional performance.

## **2.5 CONTEMPORARY NEURO-DEVELOPMENTAL TREATMENT THEORETICAL FRAMEWORK**

The theoretical framework that supports NDT is explicated through two explanatory models used to guide the choice of NDT treatment strategies and provide an explanation of why certain functional outcomes should be expected (Boenig, 2005).

### **2.5.1 Neuro-Developmental Treatment - Interactive Model**

The first is an interactive model, which represents factors that influence a person's functional abilities, and is illustrated in Figure 2.2. NDT originated through the work of Dr. Karel and Mrs. Berta Bobath, a physician and physiotherapist team, who's combined work was based, respectively, on scientific inquiry and clinical observations. Working in London from the 1940's, they observed positive changes in individuals following application of their 'Bobath Approach', which they termed 'neurodevelopmental therapy'. The Bobaths described neurodevelopmental therapy as a 'living concept', as they expected that the theoretical concepts that supported its use would develop and change over time (Howle, 2002; Kramer & Hinojosa, 1999). Howle (2002, p.315) cites Dr. Bobath (1980, p.77): "The concept developed here should be considered as no more than a working hypothesis to explain the observed facts". The successive transition from a long standing traditional paradigm to another contemporary paradigm, though frequently suppressed or rejected by traditional adherents, may mirror a developmental pattern in any social science and may involve a "revolution", or a marked shift in conceptual basis and associated practices (Kuhn, 1996, p.12; VanSant, 2008). Bly (2000) suggested that this evolution from a longstanding traditional NDT

paradigm to the more current practice in NDT constituted such a Kuhnian ‘paradigm shift’ which mirrored a movement towards a new theoretical viewpoint of NDT in the United States. It is this theoretical framework that continues to guide current practice in NDT (Bly; Rothwell et al., 2005), and underpins the present study.

There are several aspects to this paradigm shift that are pertinent to this current research. First, there was a ‘shift’ from the assumption that by directing therapy *only* to develop motor capacity, generalisation to function would result. Working directly ‘within the task’ became more common as motor learning principles were increasingly applied to the structure of NDT intervention (Bly, 2000; Halfens, 2004; Kaplan, 2002). Motor learning theory came to be recognised as equally important to NDT theory as the motor development and motor control theories had always been. The concept of motor control relates to the control of posture and movement for actions in daily tasks. Motor development describes a progression through the lifespan with general consistency in timing of acquisition of motor skills. Motor learning relates to experience and practice and leads to relatively permanent changes in the individual’s motor behaviours. NDT, in always addressing function, addresses all three: motor control, motor development, and motor learning. Treatment addresses the development of control of posture and movement within specific daily tasks and the child also actively engages in trialing task related, self initiated control and movement (Bly, 1991; Howle, 2002, 2005).

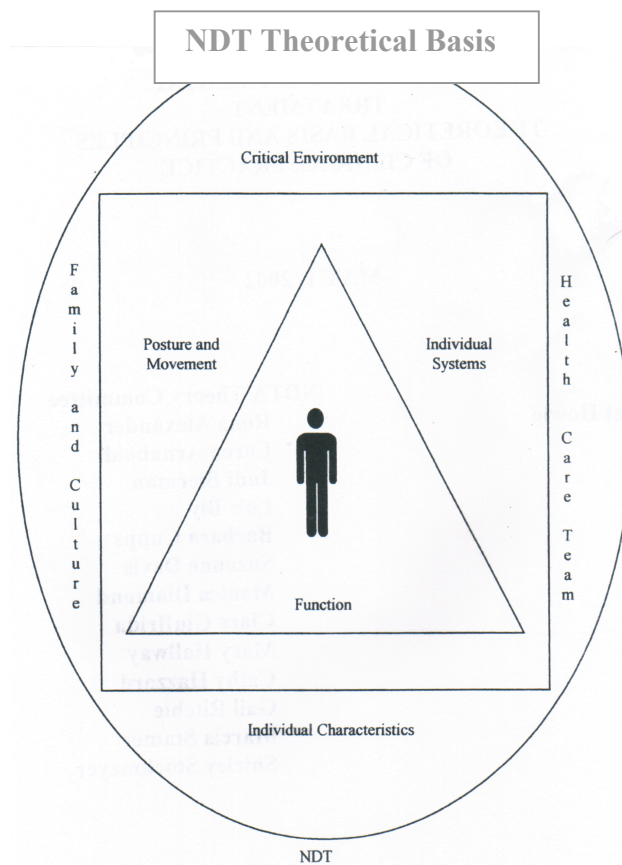
Motor learning theory was used to develop explanations about how children with CP were *learning* motor skills through repetition and practice in NDT intervention sessions, aiming towards not only a permanent change in motor skill, but in the

translation of motor skill into function. Phases of motor learning such as planning, self-initiation and varied practice are now incorporated into current NDT theory and its practices (Berry & Ryan, 2002; Bly, 1991, 2000; Breslin & Ryan, 2002; Halfens, 2004; Howle, 2002; Jonsdottir, Feters, & Kluzik, 1997; Kaplan, 2002).

Second, analysis and intervention for kinesiological and musculoskeletal issues in task performance became more important within the contemporary view of NDT. These dimensions of performance had been largely ignored in earlier NDT frameworks that were characterised by a predominant focus on motor control from the perspective of the central nervous system only (Bly, 1991; Boehme, 1988; Howle, 2002).

Figure 2.2 represents the current *NDT theoretical framework*, which reflects the amalgamation of a central system and peripheral body system view of performance. It depicts two concepts of ‘individual body systems’ and ‘postural and movement control’ which, when combined, form an ‘interactive systems model’ upon which the contemporary NDT framework is based. The control of motor behaviour, including postural and movement behaviours, is described as being distributed among interactive neural and body systems that are spontaneously organized by the task parameters in the context in which the task occurs (Howle, 2005). For example, for the play task ‘pushing a loaded toy wheelbarrow’, the following components of postural and movement control, spontaneously organized by the task and distributed between ‘interactive’ neural and body systems, may be included: coactivity of sustained neuromuscular (neural) system based muscle firing of deep abdominal and gluteal postural musculature, initiation of ‘movement musculature’, firing of concentric triceps and serratus anterior, musculoskeletal

(body) system based ‘endurance’, together with maintenance of visual vigilance (regulatory and visual systems).



**Figure 2.2:** Neuro-Developmental Treatment theoretical framework - the concept of ‘individual body systems’ together with ‘posture and movement’; depicting the relationship between human movement and human function (Hazzard, 2002; Howle, 2002).

The individual person, depicted centrally, is the central concept around which other aspects of the framework are positioned. Contextual factors and personal characteristics, family, cultural and health team factors are also recognized as impacting on a person’s function (Hazzard, 2002; Howle, 2002), and are represented in the surrounding circle in Figure 2.2. The ‘interactive systems model’ has been based on both dynamic systems theory (Bernstein 1967, cited in Howle, 2005, p.16) and neuronal group selection theory (Edelman, 1992, cited in Howle, 2005, p.16 ; Hadders-Algra, 2000; Howle, 2002, 2005).

## 2.5.2 The Neuro-Developmental Treatment Enablement Classification of Health and Disability

The *NDT Enablement Classification of Health and Disability* could be viewed as an emerging associated ‘model of practice’ that guides treatment intervention, and is illustrated in Figure 2.3.

THE NDT ENABLEMENT CLASSIFICATION OF HEALTH AND DISABILITY		
+ D O M A I N S -		
D I M E N S I O N S	Dimension	Disability Domain
	A. Body structure and functions	Structural and functional integrity Impairments A. Primary B. Secondary
	B. Motor functions	Effective posture and movement Ineffective posture and movement
	C. Individual functions	Functional activities Functional activity limitations
	D. Social functions	Participation Participation restriction

**Figure 2.3:** The NDT Enablement Classification of Health and Disability, based on the ICF Model, World Health Organization, 2001 (Howle, 2005).

The ‘Enablement model’ is adapted from the International Classification of Function ‘ICF model’ (Stamer, 2006b; World Health Organisation, 2001) and demonstrates the aim of NDT, which is to move the child along the continuum from the disability domain towards the functional domain. In this ‘enablement model’ a relationship is assumed to exist between the following concepts: NDT directed to specific activity related system impairments, and a resulting improvement in function (Howle, 2002). To facilitate functional change along this continuum, occupational therapists (OTs), physiotherapists (PTs) and speech/language pathologists (SLPs) (Maenpaa, Sanstrom, Airi, & von Wendt, 2004) work in multidisciplinary teams with infants, children and their families using the following *stages in the NDT process* (Boenig, 2005; Breslin & Ryan,

2002; Corn, 2004; Law, Oi-Sheung, & Sui, 2004). The NDTA is currently modifying the NDT enablement model to a new 'ICF model' for easier communication with the international community; in addition a new NDT practice model has been developed (Bierman, 2012).

First, *functional assessment using task analysis methods* is utilized in every intervention session to identify the child's activity strengths and limitations in performance related posture and movement behaviours that assist or impede task performance. Ahl, Johansson, Granat, and Carlberg (2005) suggest that the benefits of ongoing task analysis lie in determining the sub-skills and practice needs of children. The system impairments underlying the assessed behaviours are considered rate-limiting factors, and are addressed as part of NDT intervention to improve specific function in the task performance. Examples of such rate-limiting factors include bony restrictions, poor coordinative muscle firing, weakness, limited flexibility in soft tissue, such as excessive tightness in extrinsic hand flexor musculature, or dystonia, during phonation (for example). 'Associated' non-motor task related impairments are also addressed and may include sensory, cognitive, social and emotional factors, as well as related 'quality of life' issues (Boenig, 2005; Davis, 2004; Halfens, 2004; Howle, 2002).

Second, realistic short term functional outcomes in the form of *functional goals* are developed from task analyses for each session, and are linked to longer term goals. Outcome evaluation occurs both during and following treatment sessions and changes are made accordingly to future goals and to intervention strategies used (Bly 1991; Davis 2001, 2004; Halfens 2004; Howle 2002; Jeanson 2005; Lilly and Powell 1990).

Third, *intervention strategies* include ‘hands on’ physical prompts, verbal cues and feedback. These are gradually changed and withdrawn according to the individual needs and emerging skills of the child. Emerging skills may, for example, include increasing automatic control of skills with less cognition involved, an increase in alignment for balance, increased flexibility and range of movement, or an increase in strength (Boenig 2005; Curatti 2004; Deluca 2002; Jeanson 2005; King 1997b). Parents, if they choose, are also trained in ways to help their children apply and practice new functional skills, or parts of skills, within the context of their daily life. These are called ‘home programs’ (Mayo 1991), or similarly for educational staff, ‘school programs’.

NDT uses intervention strategies to prevent the occurrence of contractures. These strategies are used by therapists and others in the child’s context to encourage active, graded involvement of least-used body segments as required in functional activities. Repeated practice of skills that support the use of stereotypical, ‘compensatory’ movements is not used (Halfens, 2004; Stamer, 2006) as these movements may, over time, lead to secondary impairments (Palisano et al., 2004). A common example is the permanent reduction in tissue length in the shoulders and hips that occurs when excessive co-contraction is used to stiffen limbs to compensate for a lack in trunk control (Stamer, 2000).

Fourth, although NDT is largely a ‘hands on remedial approach’ in which children learn to apply new motor skills to functional performance, it also provides the foundation for prescription of *environmental adaptation and adaptive equipment* on a short term or long term basis (Barthel, 1996). Equipment has been found to

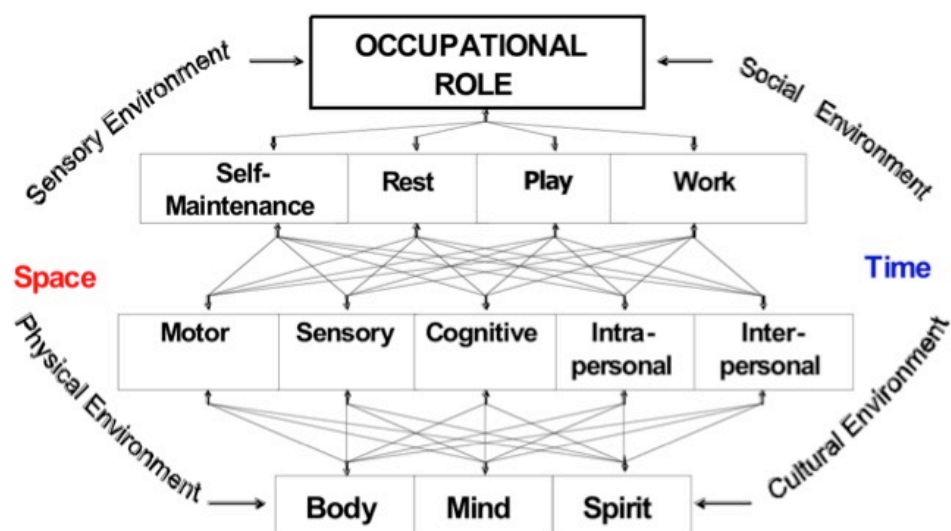
assist the function of children with CP and, in some instances, is thought to extend the gains obtained in motor skills during therapy sessions. Boyd (2001 p.4), for example, cites Nwabobi (1987) who found that the fastest times on cued seated tasks for children with CP spasticity occurred when specialised seating was in the upright position. For children with CP athetosis, this included anterior inclination (15 degrees) of the seat base. Other *adjunctive treatments*, such as the use of upper and lower limb orthoses and casting may also be utilized, such as those identified by Law et al. (1997). However, use of adjunctive strategies is selected following NDT evaluation and with continuing re-evaluation of overall functional outcome. For example, a treadmill may be utilized in an NDT intervention session to develop rotation in the lower trunk, and to assist step length to achieve a functional goal that may target walking with increased energy-efficiency (Stamer, 2006). This is in contrast to the view that NDT incorporates many techniques which are then considered integral to NDT intervention (Damiano, 2007).

The second explanatory model used to guide the choice of NDT treatment strategies and provide an explanation of why certain functional outcomes should be expected is now addressed in Section 2.6 (Boenig, 2005).

## **2.6 OCCUPATIONAL PERFORMANCE MODEL (AUSTRALIA): AN OCCUPATIONAL VIEW OF THE PLACE OF MOTOR CAPACITY IN EVERYDAY TASK PERFORMANCE**

This research study aimed to demonstrate a relationship between NDT, a mode of intervention that targets motor skills, and improved functional outcomes in children with cerebral palsy. The Occupational Performance Model (Australia) (OPM[A];

(Chapparo & Ranka, 1997) was selected to contribute to shaping this research for two reasons. Motor performance, central to this research, is identified as a key performance component in the OPM(A), and is linked directly and indirectly by interaction or relationship arrows to all constructs of occupation within the model (Figure 2.4). Second, although occupational therapists and speech pathologists have been included in multidisciplinary NDT training programs, NDT was traditionally a mode of intervention largely under the provenance of physiotherapy when the first Bobath courses began (in the early 1950's in England; 1958 in the USA), and which emphasised motor, rather than occupational, function and outcomes. As an example, it wasn't until 1963 to 1965 that occupational therapists participated in Bobath courses in England and in the United States (Blanche & Hallway, 1998).



**Figure 2.4:** Hypothesised relationship between motor performance, CP and other occupation constructs within the Occupational Performance Model [Australia] (Chapparo & Ranka, 1997).

In the OPM(A), occupation is defined as “purposeful and meaningful engagements in roles, routines, tasks and subtasks for the purpose of self-maintenance, rest, leisure and productivity” (Chapparo & Ranka, 1997, p.4). Throughout development, children use motor skills to participate in occupations that are required of them. They use these skills to perform self-maintenance occupations such as dressing and eating, rest occupations such as relaxing to go to sleep, play occupations such as playing with a ball, or schoolwork activities such as writing. Utilisation of specific motor skills to participate in these occupations is the focus of this thesis.

Central to the concept of occupational performance is the relationship between people, their context and the activation of this relationship through occupation (Baum and Christiansen, 2005; Chapparo and Ranka, 1997). People and their occupations are represented in the OPM(A) as the internal context (roles, tasks, capacities and body/mind/spirit), while the environment is represented as the external context that influences function (physical, social, cultural and sensory). Effective functional performance requires a person to possess a range of specific capacities that underpin performance and enable them to carry out activity in response to their ideas and environmental demands (motor, sensory, cognitive, interpersonal and intrapersonal)(Chapparo & Ranka, 1997).

In the case of CP, limitations to occupational performance are evident across all levels of the OPM(A)(Chapparo and Ranka, 1997). As stated in Chapter One, cerebral palsy is defined as a brain-based disorder that impacts on the capacity of the ‘body’ and the ‘mind’ to process and control motor activity during task performance. CP leads directly to changes in the structure and function of ‘body’

and ‘mind’; core elements of occupational performance. Learning to move is conceptualised as a brain-based behaviour, involving complex neural processes that convert ideas about how to move into patterns of posture and movement that are tailored specifically to each daily task (Howle, 2002). The body and mind changes that occur in CP impact on the various capacities which enable children to engage in functional activity. Within the OPM(A) model, these capacities are termed biomechanical, sensory, motor, intrapersonal and interpersonal performance capacities (see Figure 2.4). In this current research, the primary capacities of concern are the motor, sensory and cognitive capacities as they relate to the major research variable: functional outcome (role and task performance). Motor, sensory and cognitive capacities may enable or inhibit the child’s ability to learn how to participate in occupational roles, tasks and activities in childhood. Children with CP, for example, produce posture and movement behaviours that may not support their performance of everyday activities. The associated ‘feedback’ of sensory information obtained through disordered motor experience is thought to extend and consolidate learned movement errors into the child’s motor repertoire. NDT intervention utilises a ‘hands on’ mode of instruction to teach children how to use more efficient posture and movement behaviours to carry out everyday tasks. This current research investigates whether a small group of children with CP who also have reduced motor and possibly sensory processing capacities, are able to learn and use motor skills required for specific everyday tasks during and after a course of intensive NDT intervention.

Occupational performance is also influenced by the surrounding context. The environment is comprised of cultural, physical, sensory and social surrounds which exist in time and space. Active physical participation in everyday tasks is

conceptualized as a dynamic relationship between the physical context (for example home or school), expectations of amount and quality of physical performance (for example, of the parents, other children, teacher), and the demands of the task being performed (for example, the activities that have to be done in a particular place and timeframe). Stewart & Rosenbaum (2003) argue that context-based performance (what a child actually does in his or her own environment) may be quite different to performance that is seen in a clinical context. The extent to which children's motor abilities are determined to be *functional* has been described as *fit* (Rigby & Letts, 2003). The degree of fit between the motor capacity of the child and the demands of the task that has to be performed within the context it is performed has been identified as crucial to successful participation. This current research investigates whether children who receive a course of NDT intervention make changes in the degree to which their motor capacities *fit* (functional outcome) with specific tasks to the level desired by others in their context (goals), and whether this level of fit is maintained after therapy is discontinued (motor learning).

Motor activity is embedded in space and time (see Figure 2.4), which can constrain or enable success. The OPM(A) refers to the notion of 'physical space' as well as 'felt space'. This felt space is concerned with the 'meaning people attribute to space, the way they use it and their interactions within it' (Chapparo & Ranka, 1997, p.16). Similarly, time is experienced as physical time, for example the sequential or simultaneous chain of events that occur in time during dressing, or 'felt time' which is a 'person's understanding of time, based on the meaning attributed to it (Chapparo & Ranka, 1997, p.18). Children are deemed to have skilled and functional motor abilities when they produce movements that are 'felt'

by them to be sequential, timed, smooth and well calibrated in space and time. One of the characteristics of CP is poorly timed, and fragmented sequenced movements that are not calibrated to ‘fit’ the various *space* and *time* parameters where they have to be performed (Chapparo, 2001; 2009). For example, children who wish to improve their skill in using a bat and ball need to adapt their movements to fit the constraints of the objects used (space) and generate the just right timing to hit the ball with the bat (time). This current research investigates the extent to which children with CP are able to learn to calibrate their movements in space and time, specifically in accordance with the demands of everyday tasks.

In summary, this study is informed by two conceptual bases. First, current views of NDT are underpinned by the ‘interactional’ and ‘enablement’ model theoretical frameworks as described in Figures 2.2 and 2.3. NDT is conceptualised as a ‘hands-on’, engaging approach, aiming towards children achieving the highest possible participation in daily skills. Intervention is built on each family’s consideration of their child’s individual strengths and desired levels of participation at home and in the community. Second, constructs from the Occupational Performance Model (Australia) have been utilised to support the propositions underpinning the current research, which incorporates the assumption that when children are given opportunities to learn to develop motor skills within the context of occupation, their ability to engage in everyday task performance improves.

## **2.7 ‘HISTORICAL’ CONCEPTS OF NEURO-DEVELOPMENTAL TREATMENT**

While the previous introduction to NDT theory and process was developed using current NDT theory and practice frameworks, many of the research studies that aimed to investigate the impact of NDT were conducted using older NDT concepts and strategies that have since been discarded. A compilation of examples of ‘outdated’ NDT concepts are included in this section, and are contrasted with current NDT concepts as they were utilized in this research. It is argued that the negative outcomes generated by efficacy studies carried out earlier than 2000 were linked to outdated conceptual and operational definitions of NDT and cannot be considered as evidence that current NDT frameworks and interventions are ineffective.

Altering ‘movement patterns’ and ‘normalising muscle tone’, ‘positioning’ or sustaining certain positions for a length of time, or working towards ‘general development’ per se, have been replaced in current practice by a focus on actively working to achieve motor skills required for functional goals (Barry, 2001; Bly, 1991; Breslin & Ryan, 2002; Deluca, 2002; Halfens, 2004; Kerem et al., 2001; Lilly and Powell, 1990; Ottenbacher, 1986; Volman, Winroks, & Vermeer, 2002).

Earlier theoretical models of NDT were based on the concept of the CNS as a rigid hierarchical structure. Intervention, conceptualized via a ‘hierarchical model’ was structured to support, or mirror this hierarchical ordering of motor capacity, leading to the belief that lower order motor functions needed to be developed in preparation for higher order skill. Prominent in this hierarchical view was the

notion that ‘inhibition and the integration of the primitive reflexes’ was a precursor to functional motor skills. The use of intervention strategies that focused on ‘normalising’ the postural platform on which motor skills were thought to develop became one of the hallmarks of NDT. It was assumed that functional, skilled (volitional) movement would naturally follow facilitated ‘automatic’ movements. This view is no longer part of the contemporary practice of NDT. Instead, these earlier assumptions have been replaced by updated views of motor control which are built on evidence that children actively use highly skilled error detection in their motor performance, solve high level motor problems that arise during task performance, and take part in finding motor solutions to everyday functional tasks from an early age (Howle, 2006; Kaplan, 2002; Ketelaar, Vermeer, van Petegem - van Beek Hart, & Helders, 2001; Mayo, 1991; Ottenbacher et al., 1986; Puyuelo & Rondal, 2005).

The practical emphasis of ‘hands on’ intervention that was developed in earlier NDT approaches, though debated in the literature, is ‘assumed’ to be important, and so remains in the current framework. The focus is on graded ‘handling techniques’ (physical prompts from the therapist) using ‘key points of control’ (error correction of movements) within the body’s structural system (such as shoulders, pelvis, limbs) to achieve specific functional goals. The associated ‘feedback’ of sensory information obtained through these handling techniques, processed through the central nervous system, is also ‘assumed’ to be important in anticipation of and initiation of (‘feedforward’) movement in learning task related postural and movement behaviours (Bly, 1991; Boenig, 2005; De Gangi & Royeen, 1994; Halfens, 2004; Kerem, 2001; Ketelaar et al., 2001).

There is also no longer a ‘proximal to distal order’ in applying intervention.

Rather, intervention focuses on body segments and associated motor capacities that are required for particular everyday tasks. For example, in developing more efficient eating and drinking skills, intervention may focus simultaneously on ‘distal’ treatment (physical prompts) to develop hand or oral skills, together with a proximal ‘stability base’ (postural prompts) to obtain a sitting position that supports eating and drinking (Bly, 1991; Boenig, 2005; Halfens 2004; Kerem et al., 2001; Ketelaar et al., 2001) .

There was an earlier focus on the concept of ‘normalising’ a child’s ‘quality of movement’. However, since the ultimate aim for children who have cerebral palsy is increased community participation, the *current* emphasis is on active control and mastery in functional skills that are important to the child. Artificial notions of ‘normal’ movement have been discarded as an aim of intervention. Examples of skills which may be the aim of intervention include graded jaw movements in biting and chewing to enable eating, graded postural muscle control in hips and pelvis in specific floor mobility skills to enable exploratory play, or specific arm/hand reach to manipulate environmental controls (Berry & Ryan, 2002; Bower et al., 2001; Chang et al., 2005; Davis, 2004; De Gangi & Royeen 1994; Kaplan, 2002; Ketelaar et al., 2001; Law et al., 1997; Leary, 1997; Harris & Roxborough, 2005; Van Zelst et al., 2006; Volman et al., 2002).

Assumptions in earlier NDT frameworks held that strength training was contraindicated when hypertonicity was present. New developments in the movement sciences have been utilized and incorporated with NDT, resulting in

incorporation of the current practice of strength training when required (Bly, 1991; Halfens, 2004).

Although some authors in the past have asserted that parents not be involved in goal setting, parent involvement has been a part of the approach since its inception (Bly, 1991; Ketelaar et al., 2001; Law et al., 1997).

Contemporary practice in all of the therapies refers to a ‘bottom-up’ or a ‘top-down’ approach (Kolehmainen, 2010). A bottom-up approach focuses on isolated components of performance (for example, muscle tone) and is frequently assessed or treated in situations apart from real-life contexts. Bottom-up motor assessment and interventions mainly focus on body structure and function levels within the ICF model (World Health Organization, 2001). Early models of NDT align with bottom-up intervention typology. Bottom-up approaches have been criticized for reasons including (a) mismatch between the focus of therapy and the person’s functional needs, (b) unclear relationship between the person’s functional and natural performance capacity, and (c) conceptual discord between the focus of intervention and the profession’s domain of concern (American Occupational Therapy Association, 2002; Canadian Association of Occupational Therapists, 1997; Occupational Therapy Australia, 2010). In the case of occupational therapy, the domain of concern for occupational therapists is occupation. This has, at times, been at odds with earlier views of NDT that focused on development of motor capacity in children in ways that were separate from their everyday needs and contexts (Bly, 1991).

By contrast, a top-down approach assumes a global perspective, focusing on a person's participation during occupation in context (Brown & Chien, 2010). The focus is closely linked with the activity and participation levels of the ICF model (World Health Organization, 2001) and aligns with family centred approaches. Various rationales for the consideration of a top-down approach in any assessment and intervention framework have been put forward. For example, assessment and intervention strategies that focus on function clearly communicate the objective of therapy to consumers. Research has demonstrated that improvement in performance capacities (such as motor capacity), per se, has not automatically transferred to improved functional outcomes (De Grace, 2003). The weakness of a totally top-down approach lies in the inability to specifically locate the component of performance attribute that may be a 'cause' of the functional difficulty, or the 'cause' of functional improvement when it occurs.

A contemporary NDT framework could be described as offering support for using both bottom-up and top-down assessment and interventions strategies. Specific motor difficulties are identified and analysed simultaneously with functional task analysis and intervention strategies. Both aim to improve motor function during everyday task performance.

The following section will deal briefly with some details of current NDT intervention strategies. These form the 'toolkit' of NDT and are applied according to the individual, the task and the environment (Boenig, 2005).

## **2.8 CURRENT NEURO-DEVELOPMENTAL TREATMENT STRATEGIES**

Accurate description of what therapists who use NDT actually ‘do’ is important for NDT studies to be interpreted and replicated, otherwise the results will continue to be questioned (Chapman, 2004). A small sample of *current NDT treatment strategies*, the independent variable under investigation in the current research, is described below in relation to functional goals.

Hadders-Algra ([2000] cited by Goldberg, 2002, p.14) describes NDT as a “mixture of the application of handling techniques and (the) encouragement of active movement”. Many of these NDT treatment strategies, taught in postgraduate NDT training courses, have been described by a number of authors (Barthel, 2004; Blanche, Hallway & Botticelli, 1995; Bly, 1997, 1999; Boehme, 1988; Howle, 2002; Stamer, 2000;). For example, 23 principles of treatment are documented by Howle (2002), with detailed goal-based treatment strategies described by means of case studies. Examples of these descriptions are listed in Table 2.1.

**Table 2.1:** Examples of NDT treatment strategies cited in the literature.

NDT treatment strategies	
1.	Treatment approaches for <b>hypertonicity</b> or ‘stiffness’ include lengthening muscle fibres that have been held in a shortened range to assist stability. Slower movements are more effective, while fast movements are more effective in increasing muscle activity (Bly, 1991; Halfens, 2004).
2.	<p><b>Graded physical handling</b> involves use of physical cueing to assist movement. This is through external touch and or pressure cues. These cues are used to facilitate particular body segments in particular directions in space. This may need to be preceded by resolving restrictions in movements such as muscle restriction (Girolami &amp; Campbell, 1994; Eskew &amp; Dawson, 2001). In addition, developing integrated use of neck musculature for head turning in prone and supine has been described (Girolami &amp; Campbell, 1994).</p> <p>Handling cues may aim to activate certain muscles directly within an activity. For example, Davis (2004) describes treatment handling strategies for a young child with quadriplegic CP; bringing his arms forward to the midline with shoulder flexion (and external rotation with adduction), together with elbow flexion, neutral forearms, wrists extended and hands together for the goal of playing with his toys.</p>
3.	<p><b>Sensory/perceptual integration</b> with motor control is a desired outcome of graded sensory input in handling techniques through ‘feedback’ and ‘feedforward’, as a sensory representation of the current activity is built for ‘feedforward’ motor planning. These ‘sensory snapshots’ are built from, for example, somatosensory, vestibular proprioceptive and visual cues. These may lead to for example to improved alignment and stability in the current task (Breslin &amp; Ryan, 2002; Halfens, 2004).</p> <p>An example given by Stamer (2000), is for a young boy with CP athetosis to increase his visual fixation to his computer screen, while he accesses and operates his computer via a hand switch. To increase his shoulder girdle stability, he increases the pressure through his arms ‘into’ the support surface. Firstly he practices this on the moving surface of a ball, with the assistance of the therapist (to enhance touch pressure feedback), as he looks ahead to an ‘interesting target’. Then he does similarly seated at his computer.</p>
4.	<p><b>Muscle activity</b> for motor control can be addressed along the following parameters: contraction type, coordination (speed and timing), fluency, force and intensity, length of the muscle tissue, coordination with other muscles and the use ‘open’ or ‘closed chain’ movements; for example, ‘closed chain hip movement in gait, when weight is being taken through the leg, versus ‘open chained’ hip movement in the swing phase of gait. There may be interplay between these, depending upon the task. Motor activity can be enhanced using various types of treatment equipment. For example, linear movement in prone on a platform swing, carefully monitored, may increase antigravity trunk extension for a table-top task (Blanche et al., 1995; Chapparo, 2001; Eskew &amp; Dawson, 2001; Halfens, 2004).</p>

**Table 2.1: Continued.**

	<b>NDT treatment strategies</b>
5.	<b>'Grading off'</b> for increasingly active practice is important for learning to occur. The therapist moves tactile cues more distally. Verbal instructions can be decreased and fewer visual cues given. More 'knowledge of results' can be given rather than 'knowledge of performance'. The number of components being addressed until the whole task may be practiced, with guidance as required (Eskew & Dawson, 2001).
6.	<b>Grading of task demands</b> is important, for example an increasing distance to reach if focus is on extending elbow or shoulder range, or gradually challenging speed of movement or muscle force requirements (Eskew & Dawson, 2001).
7.	Preparations of <b>play activities</b> in a session to provide practice or simulation of task requirements. Structure and then variability for practice may be provided (Eskew & Dawson, 2001).
8.	<b>Adjustments to the environment</b> and the use of instructional techniques such as visual, cognitive, verbal and tactile cues can be utilized as, for example, in modelling parts of task performance, giving directions or highlighting objects with colours or textures (Breslin & Ryan, 2002; Chapparo, 2001; Eskew & Dawson, 2001).
9.	<b>Practical home or school ideas</b> , for example, can help carryover for practice and motor learning, such as hip mobilization games during nappy change time (Eskew & Dawson, 2001).

While descriptions of NDT strategies and their applications to individual children can be found in the literature, there is less information about how each strategy might influence children's function. Much of this information is generated through hypothetico-deductive reasoning (Higgs, Jones, Loftus & Christensen, 2008), where therapists identify the particular functional difficulties experienced by the child and link them to observations about disordered motor strategies that underpin function. Little published evidence supports the clinical links that are generated by this everyday reasoning process. The following examples (Table 2.2) are a number of NDT intervention strategies and hypotheses about their relationship to both system impairments and functional goals as taught in postgraduate NDT courses (Bain, 2005b).

**Table 2.2:** NDT treatment strategies and their hypothesised relationship to system impairments and functional goals.

NDT treatment strategy		Example of application of technique to promote function
1.	Elongation of muscle groups/soft tissue for joint alignment, such as hamstrings, or the latissimus musculature.	Gaining length in the hamstrings can enable the pelvis to rotate forwards in the sagittal plane for a child 'long sitting' on the floor. This in turn brings the centre of mass forwards over the base of support, which can increase balance in floor sitting for activities such as play.
2.	Facilitation of weight shifting may be combined with the strategy outlined in 1.	For example, this may apply as required in transitional movements up from the floor, from long sitting. Increased length in the latissimus musculature may allow the child, with facilitation, to rotate to side sitting, including facilitation to the contralateral upper extremity, shoulder girdle and trunk, for two hands to assist in supporting ipsilateral weight on the floor, during the transition.
3.	Treatment strategies such as resistive activities utilizing musical blowing toys.	This may assist improved strength and control of lip musculature for lip seal, in turn allowing for swallowing, including saliva control.
4.	Manual pressure directed towards the base of support to facilitate increased postural control and stability for active movement away from surface.	To improve a child's active manipulation of a hand-sized toy (held on the surface with the radial side of the hand uppermost), deep pressure is directed by the therapists' finger/s centrally into the child's transverse palmar arch (diagonally and proximally) towards the ulnar side support of the hand on the surface. This aims to improve selective finger movements from increased stability of the wrist and hand from the support base of the surface. The deep pressure is gradually decreased in response to increasing control by the child.
5.	Dynamic weight bearing and weight shifting through upper extremities in play in prone to increase co-activation in shoulder girdle musculature.	For example, control and co-activation in the rotator cuff musculature, can improve control in wide range reaching in relation to both accurate targeting and timing of reaching.
6.	Traction and vibration through the ribcage. The therapist's fingers are spread and placed approximately, for example, across the anterolateral rib cage. During exhalation, slow moving pressure with vibration is directed caudally. This facilitation aims to elongate the intercostal musculature and lengthen the duration of exhalation. It is completed with direct pressure to abdominal muscles to facilitate maximal concentric contraction for expiration. The therapist then manually 'follows' inspiration, whilst looking for an increase in ribcage expansion.	This strategy can, for example, lengthen the intercostal musculature and so expand the ribcage, towards potentially increasing respiratory volume, for breath control and phonation.

One of the desired outcomes of this current research is to provide further descriptive evidence about the impact of particular NDT strategies upon functional outcomes.

## **2.9 FREQUENCY AND INTENSITY OF INTERVENTION**

Research suggests that, in addition to the type of intervention strategies used, frequency and intensity of intervention are important for functional change to occur. Eliasson et al. (2005) indicate that both intensity and type of training are important for outcomes in rehabilitation. However, the authors also note that there is more evidence available for intensity in treatment than there is for the particular type of training.

Davis (2004) cites Schmidt & Lee (1999), who identify practice as “the most important variable when learning a new skill” (p.1). During NDT, new elements of functional tasks are practiced while the therapist pays attention to both coordination and efficiency of movement to avoid secondary impairments. Repetition and practice are further enhanced by including these new tasks in natural environments such as home and societal settings (Davis, 2004; Stamer, 2006).

Bar-Haim et al. (2006 p.329) who studied two types of intensive physiotherapy, NDT and Adeli Suit Treatment (AST), suggested that “more intensive therapy (either NDT or AST) can generally accelerate the acquisition of motor abilities in children with CP”. Both groups received 20 sessions of therapy of approximately two hours duration for five days over four weeks. They found improvements in motor skills measured for each of two groups of children with CP receiving

intensive physiotherapy in both NDT and AST format. The improvements were considered by the authors to be more than would be expected from the natural maturation of children with CP of similar ages. These skills were maintained for nine months after treatment.

Similarly, Girolami & Campbell's (1994) study with preterm infants used an 'intensive therapy' design across both an experimental and a control group. The 19 infants were assigned randomly at 34 or 35 weeks post-conceptual age to one of two groups. In each of the groups, one treated with physiotherapy (NDT), and the control group receiving non-specific handling, infants received 14 – 28 therapy sessions over seven to 17 days. The weekly NDT treatment group showed significantly improved postural control compared to the control group. They also performed better than a third group of infants who were born at term, but received no treatment. They did better than the preterm control group on motor items such as head righting and antigravity hip and knee flexion.

In another study (Arndt, Chandler, Sweeney, Sharkey, & McElroy, 2008), NDT was provided using an intensive schedule, and was hypothesized to produce changes of clinical relevance. In that study, improvement was seen in infants aged between four and 12 months who, following initial standardized testing, were found to have postural and movement deficits. The study used a repeated measures randomized block design to compare two groups of these infants. One group received NDT treatment during a three week training course for post-graduate professionals, the other group participated in a parent infant playgroup (PIP), which included enriched play activities and guidance by a Child-Life specialist. The NDT group demonstrated on the Gross Motor Function Measure (GMFM)

analysis (Russell, Rosenbaum, Gowland, Hardy, Lane, Plews, McGavin, Cadman & Jarvis, 1990) to have significantly better scores following 10 hours of treatment over a total of 14 days. These were maintained over a three week post-treatment period.

In a study of two groups of children with CP receiving NDT (Tsorlakis, Evagelinou & Tsorbatzoudis, 2004), the intensity of treatment was examined. ‘Group A’ received treatment twice a week, while ‘group B’ received it five times per week, each group for 16 weeks. While children in both groups showed significantly improved motor skills, as measured by the Gross Motor Function Measure (GMFM; Russell et al., 1990), Group B showed significantly more improvement than Group A. Fetters and Kluzik (1996) studied upper limb reaching with children who had cerebral palsy. They found that significant improvements in reach were positively related to the amount of *treatment time* in both groups in the study: one group being a ‘practice group’, the other an ‘NDT group’.

Trahan and Malouin (2002), using a multi-baseline single subject design, found significant improvements in the motor performance of five children with severe CP after NDT, using the GMFM (Russell et al., 1990). Physiotherapy, based on NDT, and ‘regular’ occupational therapy were carried out through treatment schedules of four weeks, four times per week, interspersed with eight weeks of no treatment, over a six month period. The motor skills learned were retained after treatment and the treatment was well tolerated by the children. While the children recorded a 91.1% attendance rate, it was also noted that the intervention facility offered a timely and efficient transportation system (Chapman, 2004). This study appears to

lend support for a high frequency of intervention that allows for intensive practice to consolidate skills, alternated with longer non-intervention periods. The authors did question whether targeted motor skills, when incorporated into daily living activities during the non-intervention periods had an effect and suggested the use of a daily log for records to further investigate this potential impact. Chapman (2004) points out a number of advantages of the intensive approach in Trahan & Malouin's study (2002). He included his calculation of an economic advantage, because of the comparatively long rest periods. This author also commented on the daily interaction and the benefit to the bond between child and therapist, as well as the opportunity for therapists to update goals regularly. He suggested that families benefited from the opportunity for a longer, more regular family life schedule between intensive intervention blocks.

Following Mayo's (1991) RCT, the author suggested that therapists and families should argue for more intensive therapy for children who have motor deficits. One group of children with motor delay, including CP, received a monthly 'NDT' ('basic group'). This consisted largely of a written home program. They were compared with a group who received weekly ('intensive') NDT, part of which was a home program. The latter group 'on average' scored better on a number of scales which included measurement of gross and fine motor skills, activities of daily living and hand skills, postural reactions and movements. The children's ages, gestational duration, and the mothers' education were taken into account.

While several studies have demonstrated the positive impact of intensity on carry over of function, others have not. Some authors have questioned the long-term benefit of intervention that requires large amounts of 'therapy' time and the

resulting impact of children missing out on spending time with their peers (Autti-Ramo, Anttila, & Makela, 2007). These same authors questioned whether the higher intensity treatment periods described in the studies outline above, related to requests by parents. Therapists in their study had been requested to state the range in intensity of children's treatment sessions. This varied from 45-60 minutes once per month, to three times per week.

Bower et al. (2001) in their RCT found that there was a significant 'trend' towards improved motor ability of children with CP following an intensive schedule of one hour daily for six months of mainly, 'eclectic' physiotherapy. However, this was not sustained in the following six months observation period. It was noted that participants, children and a collaborative team of parents, caregivers and teachers, found the intensive therapy period both tiring and stressful.

Law (1997) found that following NDT and casting for children with CP using two different intensity schedules, there was *no* benefit in more treatment. Examples of NDT intervention group activity included improving quality of upper limb movement and changing other physical impairments. The comparison OT group focused on task analysis of functional skills and addressed goals related to these such as self-care. Neither group showed benefit of change with increased therapy.

Corn (2004), cites Nass & Tauner (2003) who suggest that "research is beginning to demonstrate how early, appropriate and intensive treatment positively alters the outcome for infants with CNS damage and resulting motor and cognitive impairments" (p.16). Corn illustrates this point by anecdotally describing a case study of her own where NDT was included in a range of interventions utilised in

assisting the development of a five-week-old baby, recently discharged from the Neonatal Intensive Care Unit (NICU). The baby had seizures and a right cerebral artery infarct, documented by Magnetic Resonance Imaging (MRI). Impairments included high tone in the left extremities (Ashworth Scale 1+), low postural tone, severe sensory disorganization and irritability. The baby was first referred for physiotherapy in the NICU and then as an outpatient. The author describes the baby's development and monitoring by the neurologist over the first year. At 11 months of age the neurologist reported the baby "no longer had any signs of cerebral palsy, he was normal". Corn anecdotally attributes this result to the NICU care, parental involvement and the 'neuro-paediatric' intervention and NDT intervention given by the two therapists. Sharkey (1996) also studied early NDT treatment to address motor skills for infants. This study demonstrated that motor skill development was best if the referral occurred before nine months of age.

While case study design generates low-level evidence (Sackett, Strauss, Richardson, Rosenberg, & Haynes, 2000), in this researcher's experience, similar anecdotal 'evidence' is common amongst NDT therapists and families. This is particularly evident after postgraduate NDT training courses where child and family participants undertake short periods of intensive NDT, which they may have not undertaken in the past. Such stories of functional gains for children have provided the motivation for this current research which aimed to more specifically measure the functional outcomes after a similar course of short, intensive NDT intervention.

In conclusion, a number of studies with a variety of levels of evidence have documented improvement in functional skills in response to intensive treatment,

including NDT. Studies where the positive outcomes have either not occurred or not persisted at follow-up have also been documented. Overall, however, the results of the studies cited appear to support the notion that intensity of treatment is an important element in the degree of functional change following therapy.

## **2.10 EVIDENCE OF IMPROVED LEVEL OF INDEPENDENCE FOLLOWING NEURO-DEVELOPMENTAL TREATMENT IN CHILDREN WITH CEREBRAL PALSY.**

There is equivocal evidence only to support NDT, but practitioners seek recognition of NDT as an evidence-based intervention that may contribute to, and rely upon, the brain's neuroplasticity for new motor learning and recovery of function. Neuroscience research supports the concept of neuroplasticity which enables the 'potential to change' in human function (Eliasson et al., 2005; Eskew & Dawson, 2001; Liepert, Bauder, Wolfgang, Miltner, Taub & Weiller, 2000; Nudo, 1999; Nudo & Milliken, 1996). Weindling (2000) suggests that a child's development may be positively affected by "altering inputs" (p.53). NDT is one such paediatric intervention which *may* provide such inputs to effect change in children with cerebral palsy. Evidence of such outcomes, however, is scarce.

It is argued that improvements in functional skills are more likely to be significant if the NDT intervention process addresses functional skills and incorporates task analysis and practice. Research studies have not clearly generated sufficient evidence to demonstrate positive benefit from NDT (Fettters and Kluzik 1996; Siebes, Wijnroks et al. 2002). However, the following studies, which employ contemporary NDT strategies, have produced some positive evidence to support

use of NDT. Positive outcomes for a number of studies incorporating NDT as the independent variable have already been reported above in Section 2.8 of this literature review which discussed the outcomes of *intensive models of treatment* (Arndt, Chandler, Sweeney, Sharkey, & McElroy, 2008; Arndt et al., 2005; Bar-Haim et al., 2006; Bower, Michell, Burnett, Campbell, & McLellan, 2001; Girolami & Campbell, 1994; Mayo, 1991; Trahan & Malouin, 2002; Tsorlakis, Evaggelinou, & Tsorbatzoudis, 2004). Further aspects of these and other studies are discussed further in this section.

Howle (2000, p.151) cites an early meta-analysis of nine research studies involving 371 subjects with developmental disabilities or developmental delay, all under the age of 15 years. NDT was required to be at least one of the interventions in each of the 'non overlapping' studies, each of which had a comparison group of children who did not receive NDT. Outcome measures of development, which produced quantitative data for statistical analysis, were utilised. The meta-analysis resulted in reported small but positive intervention effects for the subjects receiving NDT, compared with those who did not (Ottenbacher et al., 1986).

In the Bar-Haim et al. (2006) study, which assessed outcomes of two alternate interventions, NDT and the Adeli suit and associated treatment (AST), functional aims were established for each child randomly assigned to the NDT group. These included activities such as walking, riding a tricycle or sitting more independently, during the four weeks of treatment. NDT strategies were individually determined for each child and the focus of treatment addressed the functional goals. Therapists were experienced, NDT-trained, physical therapists. Using the GMFM (Russell et al., 1990) and the Energy Expenditure Efficiency Index (Rose, Medeiros, & Parker,

1985) as measures, results showed a significant difference between the NDT group scores at baseline and at 10 months follow-up ( $p=0.006$ ). These were greater than expected from the natural development of children of the same ages who have CP (Rosenbaum et al., 2002). While the NDT results showed a slower time effect in the NDT versus AST group in this study (that is, a comparatively longer time taken to acquire motor skills), the authors reasoned that this reflected the focus on acquisition of the type of motor skills by the children receiving NDT (which doesn't follow a strict protocol but instead focuses on functional outcomes such as those related to mobility, including seating and transitional movements).

In Girolami & Campbell's (1994) randomized controlled trial of two therapy methods, infants were tested on the Supplemental Motor Test (Girolami, 1987). Blinded testers found that the NDT group performed significantly better on postural control, but not on tone, behaviour state, reflexes or autonomic regulation. Postural control gains included the infants being able: to lift and turn their heads to either side when in a prone position, to bring their hands together and to their mouth with shoulder control, and to maintain comfortable side lying towards later rolling. However, the authors felt it was encouraging that physiological stability and growth were not compromised during the treatment. Considering these functional gains and the lack of significant difference between groups prior to treatment, these results lend support to NDT efficacy. The behaviours not changed by NDT, such as change in reflex status, are not the focus of the current NDT framework. The authors did mention that the design used a small sample of 19 infants, and suggested that this study design may be later used for larger samples to confirm findings. The authors also reported that there was no long-term follow up.

In the Arndt et al. study (2008), the NDT group made significantly more progress on the GMFM ( $p=0.0475$ ) (Russell et al., 1990) than the Parent-Infant Playgroup (PIP) group. The authors developed a specific treatment protocol, unique to NDT and operationally defined, and applied it under experimental conditions (Howle 2008). The NDT treatment strategies that were employed related to developmental sequences of movement, with postural control as the functional goals. These were considered appropriate 'functional goals' for babies of this young age, when the emphasis for the babies may be on time spent developing the kinesiological control for developmental milestones, rather than following an ordered developmental sequence (Bly, 1991). The assessor, reported to be reliable, was blinded to group assignment of the infants being assessed. It was suggested that supervision of the treating NDT therapists in the course during which the study was done, ensured that the NDT treatment was carried out appropriately for each infant. This is relevant to Phase Four of the current study, which also occurred during a postgraduate NDT course.

Evaluation occurred prior to and immediately after the 14-day treatment period, and at three weeks follow-up. Significant change occurred from pre-test to follow-up ( $p=0.011$ ). The authors of the study (Arndt et al., 2008) reported that significant motor gains were made but that at the three week follow up, these gains were less robust.

Tsorlakis, Evaggelinou and Tsorbatzoudis, (2004) studied the impact of NDT on gross motor function of 34 children with CP. Pairs were matched for age, sex and impairment distribution and were randomly assigned to two NDT treatment groups of different intensity, one acting as a reference group, rather than a control group.

In this study, both groups improved significantly in gross motor function activities ( $p < .05$ ), such as walking, climbing stairs and kicking a ball. In pre- and post-tests, mean scores were compared on the GMFM (Russell et al., 1990) and the results support the use of NDT in improving the performance of daily tasks by children with CP. This is especially important considering that for these children with CP, the absence of secondary impairments and regression is a positive result (Van Zelst et al., 2006). However a criticism of the study is that due to ethical factors, there was no 'true' control group. The authors described how 30 of the 34 children made functional gains. They also point out that results are only applicable to children with spasticity, which reflected the sample of children in the study.

In Trahan and Malouin's (2002) study, significant improvements in the motor performance ( $p < 0.05$ ) were scored on the GMFM (Russell et al., 1990) for a small group of children. Three of the five children with severe CP showed improvement. Four of the children were classified as Level IV on The Gross Motor Classification System (GMFCS) (Palisano et al., 1997) and the other child at Level V. Children who had conditions that may have interfered with the study were excluded, such as those awaiting surgery. There was no control group, so the treatment regime may not have caused the motor improvements. Chapman (2004), in reviewing this study, considered that the trends shown in multiple baseline measures support the premise that intervention was associated for the changes. Scoring was carried out by a therapist unaware of the children or the study and who didn't have knowledge of earlier assessments. Evaluation of the fidelity of the NDT intervention in this study is difficult as it was not described. Therefore it is difficult to determine the extent to which functional goals were the basis for the NDT intervention provided.

In the preliminary study by Knox and Evans (2002), which evaluated the functional effects of Bobath Therapy in children with CP, significant functional gains in self-care and mobility were made by 15 subjects. These children were classified as having a variety of types and severity of CP. They participated in a six-week block of individual NDT sessions with expert NDT clinicians. Comparisons were made using a repeated measures design using the Gross Motor Function Measure (GMFM; Russell et al., 2000) and the Pediatric Evaluation of Disability Inventory (PEDI; Haley, Coster, Ludlow, Haltiwanger & Andrellos, 1992), which were administered before and after treatment and in follow up. The study was limited by the sample size, and the children acting as ‘their own controls’, leading to speculation about whether treatment effects were beyond what may have been ‘spontaneous recovery’. The authors did, however, provide details of the degree to which functional goals were achieved (Table 2.3).

The study by Jonsdottir et al. (1997) showed significant positive benefit from NDT in improving postural alignment in a reaching task involving eight children aged 10-15 years who had CP ( $p < 0.05$ ). Subjects had all been assigned to two groups: a practice group for 35 minutes per day for five days, and the same schedule for individual intervention as part of an NDT group, with each group working on a reaching goal. In the week prior and between treatment weeks, no therapy occurred. Posture was analysed and assessed using kinematic analysis and videography. Significant benefit was only apparent when data of one ‘outlier’ subject were eliminated. In Harris and Roxborough’s review of this study (2005), it was noted that there was no overall significant effect on postural control in sitting by either group.

**Table 2.3:** Functional outcomes and their statistical significance following six weeks of Bobath neuro-developmental therapy (Knox & Evans, 2002a)

Functional Outcomes	Statistical Significance
<b>Gross Motor Function Measure (GMFM)</b> <ul style="list-style-type: none"> <li>• GMFM total scores.</li> </ul>	p = 0.009
<ul style="list-style-type: none"> <li>• GMFM-66 (increased sensitivity) scores (Russell et al., 2000).</li> </ul>	p = 0.03
<ul style="list-style-type: none"> <li>• Independence in walking and crawling.</li> </ul>	p = 0.010
<b>Pediatric Evaluation Disability Inventory (PEDI)</b> <ul style="list-style-type: none"> <li>• Self-care (such as self-dressing and personal hygiene e.g. grooming and bathing).</li> </ul>	p = 0.031
<ul style="list-style-type: none"> <li>• Caregiver assistance required for daily living skills such as transitional movements, locomotion indoors and outdoors, managing stairs.</li> </ul>	p = 0.015
<ul style="list-style-type: none"> <li>• Caregiver assistance required for aspects of self-care such as dressing and personal hygiene – for example brushing teeth and nose care.</li> </ul>	p = 0.036

In conclusion, a number of examples of efficacy of both NDT and intensity of treatment have been presented from the literature. While these offer some support for the use and intensity of NDT interventions to affect functional outcomes in children with CP, there are limitations in aspects of the methodology and power of the studies, as outlined.

## 2.11 FUNCTIONAL OUTCOME MEASURES

This part of the literature review focused on a search for the most appropriate outcome measures that can be most effectively used in NDT research to, for example, measure small increments of functional change based on specific functional goals (Barry, 2001; Harris, 1981; Lilly & Powell, 1990). Prior to

addressing outcome measures, the concepts of function, functional goals and functional change will be further defined.

The diffuse and multidimensional nature of ‘function’ makes it difficult to measure functional change in research (Unsworth, 1993). Definitions of function generally refer to activities and actions that are in turn the ‘expected’ roles or occupations of people, while the adjective ‘functional’ implies effectiveness (Bernhard, 1984; Editors of the American Heritage Dictionaries, 2007; Zeitgeist, [n.d.]). Function, for children with CP may be best defined according to the meta-occupational roles of player, worker, and self-maintainer enacted through the following occupational tasks: self-maintenance, productivity (for example at school) and leisure and social function, both at home and in the community (Law, 2008; Ranka & Chapparo, 1997).

Function is also contextually specific (Anthony, Cohen, Farkas & Gagne, 2002). Function, therefore, depends upon the attributes of the *specific functional task*. For example, in a manipulation task, there may be particular requirements such as simple manipulation, or additional requirements of speed and accuracy and increasing postural control. Other writing task attributes of function may include variability, flexibility, stability and mobility. Task analysis is the process used by NDT to determine each attribute or component of function in a task. Variations in conditions in the environment also impact on function within a task; for example, writing seated at a table or while moving (Chapparo, 2001; Shumway-Cook, 2006). Functional skill in the infant is described as first developing through activation of selected neuronal connections in the brain (neuronal group selection). These are repeatedly selected and used, and so reinforced by the infant to become ‘favoured

functional neural circuits' and muscle synergies (Rdelman 1992, cited in Howle, 2002, p. 24)). An example is an infant learning to control the motor actions of reach by using visual information to guide reaching to play (and so reinforcing 'favoured neural circuits').

NDT, as previously outlined, is based on the International Classification of Function (ICF) model (World Health Organization, 2001). This model describes function as both the capacity to perform an activity and the ability to do so when participating in 'real life'. This also reflects the overall objective of NDT, which employs measurable functional goals to guide treatment.

### **2.11.1 Measuring change after Neuro-Developmental Treatment**

As outlined in previous sections of this chapter, clinical reasoning, expert opinion, and evidence suggest that providing NDT intervention within the context of task performance enhances outcomes. The rationale for intensive intervention is that the 'hands on' physical prompts used in this form of therapy may provide an opportunity for muscles that have atypical tonus and action, to be controlled for a specific functional purpose. Concurrently, motor and physical interventions (for example, casting, motor learning techniques) can be used within an NDT framework to guide and direct children's responses to altered muscle states and to assist them to learn new and more functional posture and movement behaviours. Many methods that have been used to assess these purported outcomes are inadequate to conclude whether or not NDT promotes meaningful participation in functional day-to-day activities. They can only be assumed to have an association with the use of the body in functional activities (Howle, 2002; Jankovic, Esquenazi, Fehlings, Freitag, Lang & Naumann, 2004).

The following two studies, though not resulting in significant change following NDT, offer guidance regarding the development of suitable measurement tools, and have contributed to the methods used in this current research. First, De Gangi's (1994) case studies document many functional changes in six children aged between one and six years with a variety of types of CP. The study demonstrated, through the inclusion of functional goals and clear descriptions of NDT interventions, that the link between NDT and functional outcome was different for each child. Each child in De Gangi's study (1994) received two sessions of NDT per week for an eight-week period, as part of their overall therapy management. Independent multiple measures of change were used in pre- and post-testing, including standardized tests, questionnaires and videotaping. The following goal examples for a two year old child, who had made minimal progress in motor skills the previous year, were included: to produce sounds, to sit independently and to reach and grasp with her right hand. Results following NDT for this infant included increased use of her right hand in reaching and grasping while using, for example, her cup at home. On the Peabody Development Motor Scales she had progressed two to three months in general fine and gross motor skills. In addition, the authors described therapists' qualitative observations of motor and functional change that were not quantified in the study.

Similarly in Lilly and Powell's (1990) single subject design study, there were no significant positive results obtained in dressing skills by the two children with CP following NDT or play. Evaluation by 'blinded raters' was from videotape, using a measure that utilized an ordinal scale. It was developed by the researchers to identify small increments of functional change in goals. However, the researchers questioned the inter-rater reliability of the raters and cited insufficient training to

enable them to identify and measure motor change that was embedded within functional performance.

### **2.11.2 Methods Used to Measure Change: Video Motion Analysis**

Lilly and Powell (1993) and De Gangi et al. (1983) suggested that future computerized videotape analyses of functional movements, could improve sensitive analysis of changes in task performance. These could then be recorded in *ratio* scaling, that is, would allow the use of quantitative measurement scales with an ‘absolute zero’ for pre- and post-comparison. Examples of scales include: time, angle of movement, or length of trajectory.

Many kinematic studies in a laboratory context have been used to measure change in such variables from pre- to post-intervention (for example, Chang, Wu, Wu & Su, 2005; Neumann, 2002). However, video footage has not been so easily captured in the clinical context. If the objective of intervention is make change to motor performance within a task context, and in situ, filming methods must be used within that situation. Examples of studies using video analysis will be briefly reviewed.

Lilly and Powell (1990) videoed the following parameters in the dressing tasks: initiation of movement, shoulder motion, trunk rotation, balance in sitting, spontaneous use of upper extremities, and ‘excessive’ body movements. De Gangi, Hurley and Linscheid (1983) used videotaping for later scoring by trained psychology students.

‘Live assessment’ is captured on videotape so scoring accuracy is enhanced through repeated viewing, including frame-by-frame analysis as utilized by Jonsdottir, Fetters and Kluzik (1997). Chakerian and Larson (1993) used video analysis to find an overall significant increase in the abilities of ten children with CP to reach, grasp and release set toys during play after weight bearing through the hands. In a related field, the effects of botulinum toxin A (BTX-A) and an oral pharmacological treatment for children with dystonia were compared by video observations that had been transferred to a scale (the Tsui Rating Scale; Muller, Wenning, Wissek, Baldorf, Seppi, Brenneis & Poewe, 2001).

As suggested by earlier researchers using motion analysis (De Gangi, Hurley, & Linscheid, 1983; Lilly & Powell, 1990), computerized motion analysis video software may provide the best measurement tool of subtle physical changes following NDT. While the technology has been available to laboratory research for a while, its translation into the clinical situation has been scarce. As an example, computerized motional analysis video software could be used with video captured in the clinic to quantitatively analyse gains made related to a ‘bat and ball game’ goal. For example, an increase in trunk rotation range, observed to improve bat swing, could be measured in this way.

### **2.11.3 Methods Used to Measure Change: Goal Attainment Scaling**

Goal Attainment Scaling (GAS) is a well-tested, reliable and valid paediatric intervention outcome measure (Cardillo & Smith, 1994; Ottenbacher & Cusick, 1989). Goal Attainment Scaling is an ordinal scale used to document goal based functional behaviours, and to identify any changes following intervention. The

baseline behaviour is recorded at the -2 level on the scale and the realistically expected level of outcome described at the 0 level. The behaviour descriptions are clearly written in quantitative terms, such as frequency or intensity of the behaviour. In addition 'somewhat more' and 'somewhat less than expected' outcomes for the child are respectively written into the scale at the -1 and +1 levels, and the 'much more than expected' outcome level (estimated to relate to five to ten percent of the clients) is written in at the +2 level. Description of behaviour at each level is mutually exclusive without overlapping or 'gaps' in the level of function described through the scale. Separate subscales each relate to a single measurable parameter of the functional goal (Cardillo & Smith, 1994). Goal Attainment Scaling is considered to be to be an effective long term monitoring tool for children with CP, and can be used when no standardized measure exists to measure certain 'attributes' (Wallen, O'Flaherty, & Waugh, 2004).

Reliability is best when 'extra' scales are included to control for 'floor or ceiling' effects and is also improved with multiple measurement periods. Reliability also improves when it is used by experienced 'goal setters'. Precision in goal setting is an inherent process within the current practice of NDT, therefore the use of GAS as an outcome measure was explored in preparation for the current study.

GAS scaling has been used effectively with two 'adjunctive' NDT interventions. First, GAS was used effectively to measure the effects of BTX-A (Botulinum Toxin - A) injected into hip adductors on subsequent activities such as walking and personal hygiene (Mall et al., 2006). In another study, GAS was used to measure functional outcomes following injection of BTX-A into the upper limb. Some goal areas in that study included, leisure time pursuits, a variety of self-care skills,

school skills, and being able to catch a ball (Wallen et al., 2004). Second, it has been used to evaluate the outcome of upper extremity electro- stimulation as an adjunct to 'regular' OT and PT for children with CP hemiplegia (Maenpaa, Sanstrom, Airi, & von Wendt, 2004).

According to the following authors (Maloney, Mirrett, Brooks, & Johannes, 1978; McLaren & Rodger, 2003a; Sakzewski, Boyd, & Ziviani, 2007), GAS is an outcome measure able to measure small functional changes, especially by children who have severe and profound disabilities. It is criterion referenced, and weighting of goals enables statistical analysis via conversion to T scores. It can be quickly scored in the clinic, once the scaled goal statements are recorded.

GAS can be used to reflect 'theoretical emphasis', such as the emphasis on the link between motor capacity and function in NDT. It provides a flexible measure for stating 'reasonable' short-term objectives which can be clearly viewed in the scale. Its scaling is 'practice-based' and it allows for collaborative goal setting, for example, with parents. Valid conclusions can be drawn from functional changes recorded on the GAS scale as the scale allows for recording of change in goal performance at the -1 to +2 level, and allows for 'no change' to be recorded at the -2 level (McLaren & Rodger 2003b). In addition, Palisano et al. (1992, cited in McLaren & Rodger, 2003, p. 220) "investigated the validity of GAS as a measure of change in motor performance as a result of therapy of 65 infants with gross motor delay. They found it to be responsive measure of change in individualized motor-based goals".

However, there are some limitations in using GAS scales. It does take time to develop the scale, to retest and score for each child (Sakzewski, Boyd, & Ziviani, 2007). If significant deterioration occurs in progressive conditions, it is not able to be recorded on the regular -2 to +2 scale (Law, Oi-Sheung, & Sui, 2004).

However, there has been some work done to extend the scale (-3 and +3) to allow for floor and ceiling effects (Novak & MacIntyre, 2006; Steenbeek, Ketelaar, Galama, & Gorter, 2007). Finally, GAS documents 'goal statements' only and does not itself account for the *reasons* for changes in function. Consequently, it can not be concluded that an intervention under study was causative of an increase in a GAS score following intervention. For example, change from natural recovery, rather than the intervention, may need to be considered when interpreting scores (Lannin, 2003).

GAS functional outcome measurements can be convincing in times of fiscal restraint and accountability for funding reasons (Mitchell & Cusick, 1998). Goals are set at an expected or desired outcome level (level 0, where pre-test is set at -2). Children with CP can require PT, OT and SLP over relatively long periods of time, so objective justification provided through outcomes-based treatment approaches, such as NDT, may be important (Maloney, Mirrett, Brooks, & Johannes, 1978).

GAS can also be used to evaluate programs and is able to measure outcomes despite diagnosis, severity or the treatment program being used (Lannin, 2003). In conclusion, it appears that GAS is a suitable measure for putting into operation, targeted functional goals, thus allowing quantitative measurement of small increments of change following NDT.

## **2.12 DIFFICULTIES IN ESTABLISHING EVIDENCE OF NEURO-DEVELOPMENT TREATMENT EFFICACY**

In aiming to establish evidence of NDT effectiveness, it has been argued that methodologically robust and powerful research designs must be chosen.

Randomized, controlled trials are examples of these (Cadman et al., 1989; Lannin, 2003; Ottenbacher, 2001). Practitioners are then able to make informed, judicious, and accurate decisions about NDT as ‘best practice’ for individual children (Barry, 2001; Ottenbacher, 2001).

However, there are difficulties in carrying out such research, resulting in the sample of negative or equivocal study outcomes described below. Sharkey et al. (2002) and others suggest the following reasons. First, suitable groups of children with CP who are included in studies are generally small and heterogeneous. Second, the existence of ethical difficulties regarding control groups inhibits planned research. Of particular note, is the stress for families traveling to be involved in a ‘no treatment’ control group. Third, there is a lack of suitably sensitive, validated and standardized outcome measures. Fourth, lack of a set of working definitions on what is exactly being measured, stemming from that fact that NDT is not ‘one treatment’, but an *approach*, with many specific intervention strategies, as described earlier in this chapter (Siebes, Wijnroks, & Vermeer, 2002). Fifth, as stated above, CP is a diagnosis that contains multiple and individual manifestations leading to a large range of possible functional outcomes. Sixth, functional skills may take time to be consolidated after a term of NDT intervention, and the results of the intervention may be missed. Seventh, there is a wide variability of physical and social environments in which functional tasks are

performed, leading to difficulty in establishing a measurement model that reflects functional change. Eighth, there is difficulty controlling for other treatment effects and compliance, particularly in children where, for example, treatment is missed through family illness. Finally, the eclectic nature of NDT and outcome measures not being validated may lead to inconclusive results (Barry, 2001; Campbell, 1989; De Gangi, 1994; Halfens, 2004; Ketelaar et al., 2001; Kolobe, Palisano, & Stratford, 1998; Mayo, 1991).

Weindling (2000) reported, that there is no clear guidance from the literature about which treatment is the most effective for children with CP. Negative or equivocal outcomes relating to NDT research include the following. Butler and Darrah, (2001) and Volman, Winroks and Vermeer (2002), found no evidence for effects on overall motor function after NDT when they reviewed NDT efficacy studies. Similarly, infants at high risk for developmental motor disorders were treated in the NICU and at home (Blauw-Hospers & Hadders-Algra, 2005). Compared with Newborn Individualised Developmental Care and Assessment Program (NIDCAP), NDT was not found to have a beneficial effect on motor development. In both these studies, the fidelity of NDT treatment used was not demonstrated and it was therefore difficult to determine whether it was directed towards functional goals as described in Girolami's study outlined above (1987). For example, it appeared from the research reports, that the handling was 'passive', rather than 'active' handling; a central component of Neuro-Developmental Treatment being encouragement of active movement by the child rather than passively moving the child. In addition, other examples of the interventions included 'general' sensory stimulation, rather than specifically directed sensory inputs related to the achievement of motor goals, as is the case with current NDT intervention.

One systematic review of interventions for children with CP (Steultjens, Dekker, Bouter, van deNes, Lambregts, & van den Ende, 2004) did not include NDT, probably due to lack of high level evidence available for review. This is important when it is considered how many parents seek, and must choose, an effective therapy for their children (Adams and Snyder, 1998); for example, often choosing additional therapy in a specialist education field, such as a special development school (Parkes, Donnelly, Dolk, & Hill, 2002).

Brown and Burns (2001) reviewed 17 studies, but only four studies demonstrated statistically significant benefit of NDT. Two of these, however, included a second treatment, such as surgery or casting, and were therefore not included in the analysis. It could be argued that as NDT is clinically practiced in combination with other adjunct therapies, such studies should be included in any review of impact. Cayo (2000) provides one such example in a study that investigated the use of NDT to improve components of functional task performance in combination with use of a constraining cast, for children with hemiplegic CP.

The remaining two studies in Brown and Burns (2001) review were performed in 1975 and 1978. However, it can be argued that as all 17 studies reviewed were dated between 1975 and 1998, important components of contemporary NDT practice were missing as outlined in an earlier section of this review. The authors did mention the importance of the development of postural and movement control *within* daily tasks, but did not recognize this as an integral part of the NDT practice that was evaluated (Adams & Snyder, 1998).

It may be suggested that, just as these studies indicate there is no evidence to support the use of NDT (Adams & Snyder, 1998; Brown & Burns, 2001; Steultjens et al., 2004), the studies that were reviewed do not represent current NDT operational definitions, and that therefore, neither can their findings conclude that contemporary NDT is an ineffective framework for improving the level of independence of children with cerebral palsy in the performance of daily living tasks. Sharkey, Banaitis, Guiffrida, Mullens, Rast, & Pratt (2002) assert that the “absence of evidence of effectiveness in an evidence report cannot be construed as proof that a treatment is not effective. Rather it may reflect areas in which more meaningful research is needed” (p.7).

### **2.13 PARENT INVOLVEMENT**

NDT is considered a family-centred practice and parents are involved in current NDT practice with their children. For example, in De Gangi & Ryeen’s study (1994), 89% of respondents viewed NDT as considering a child’s function across many settings, such as at home and at school. The respondents were experienced therapists most of whom were certified in NDT. A wide range of parameters may be used in defining family-centred practice. They may include services that are provided at home and parents being actively involved in making decisions within the organization providing the services for children. Law et al. (1997) found the largest, though not significant, improvements occurred with the children whose goals were identified by their parents. The evidence base of NDT could be supported by these results being the primary outcomes investigated in NDT efficacy studies. Other authors also refer to the positive effects associated with

parent involvement in setting goals, and from carryover and practice at home (De Gangi, 1994; Ketelaar et al., 2001).

Ahl et al (2005) reported that participation in the treatment of their children gave parents confidence in their abilities to help their children. In Okimoto et al. (2000), significant improvement in playfulness was found in children with CP whose mothers were included. Just a small sample of two of the children in the NDT group (with their mothers) had significantly improved 'playfulness', but these results *may* support parental involvement in NDT. The parental involvement was 'assisting' during the therapy, such as holding toys for the child to reach out to.

Kaplan (2002) suggested surveying parents for evaluation and suggestions for NDT programs, and described a flexible method to tailor the survey to the parents needs.

Bower et al. (2001) used the Measures of Process of Care (MPOC) Parents' questionnaire (King, 2002). This related to the care their children received in therapy programs. It could, for example, be used at the beginning of treatment and at six monthly intervals to both improve NDT programs and provide evidence of parent and child benefit.

## **2.14 FINDINGS**

The purpose of this literature review was to address the overall research question which was: *What is the impact of NDT on the functional outcomes of children with cerebral palsy as measured by their performance in selected daily living tasks?*

The review generated several findings relevant to the major variables and methods used in this research. The findings are summarised below, beginning with the

major variables followed by findings related to the outcome measures used in this research: video motion analysis, and Goal Attainment Scaling and family's perceptions in relation to NDT.

### **Finding 2.14.1**

Cerebral palsy is the most common cause of severe physical disability in childhood (Lin, 2003; Koman et al., 2004, cited in Steenberg and Gordon, 2006; Stanley, Blair and Alberman, 2000). The children comprise a heterogeneous group with a wide range of functional problems. This results in families and service providers seeking evidence to guide best intervention for current needs and for the changing condition over time.

### **Finding 2.14.2**

Daily living tasks of primary concern in measurement of functional outcomes of intervention for children with CP include the following categories of daily function: self-care, mobility, hands skills, communication, educational and vocational skills, leisure pursuits and play (World Health Organization 2001; Howle 2002).

### **Finding 2.14.3**

The current NDT theoretical framework is comprised of the revised theoretical base and practice model of the Neuro-Developmental Treatment Association of North America (NDTA<sup>TM</sup>; Howle, 2002). Current NDT intervention targets specific functional outcomes in order to increase children's participation and independence and is underpinned by two conceptual bases: the NDT 'interactional' and 'enablement' models and is supported in this research by constructs from the

Occupational Performance Model in Australia (Chapparo & Ranka, 1997; Howle 2002).

#### **Finding 2.14.4**

Current NDT treatment strategies incorporate task analysis to measure intervention outcome. Each session of ‘current NDT’ intervention involves pre- and post-testing, task analysis of families’ functional goals and treatment strategies that target the related posture and movement behaviours. Specific operational definitions of interventions were provided. These include graded physical handling within engaging activities, use of sensory cues (e.g. traction, resistance or vibration) and practice encouraging active movement, built on the child’s existing strengths (Bain, 2005a; Blanche et al., 1995; Bly, 1991; Chapparo, 2001b; Eskew & Dawson, 2001; Girolami & Campbell, 1994; Halfens, 2004).

#### **Finding 2.14.5**

There is equivocal evidence to support use of NDT in practice. From the relatively small number of studies attempting to determine the efficacy of NDT intervention related to functional outcomes, there is currently no empirical consensus showing that NDT is more valuable than other therapies, (Anttila, Suoranta, Malmivaara, Makela, & Autti-Ramo, 2008; Bar-Haim et al., 2006; Berry & Ryan, 2002; Fetters & Kluzik, 1996; Jeanson, 2005; King, 1997a, 1997b; Siebes, Wijnroks, & Vermeer, 2002). There are many methodological difficulties in carrying out NDT research that, for example, relate to the heterogeneous nature of CP, the capacity to measure small increments of change, and the ethics surrounding the use of RCT methodologies.

### **Finding 2.14.6**

There is a small body of evidence of improved function in children with CP after NDT intervention. Specifically, studies that have employed contemporary NDT have produced some positive evidence to support its use. There are limitations in aspects of the methodology and power of these studies.

### **Finding 2.14.7**

Research suggests that high levels of frequency and intensity of intervention need to be present for functional change to occur, but less evidence is available for the particular intervention.

### **Finding 2.14.8**

Video capture and computerized motion analysis video software may provide the best measurement tool of subtle physical changes following NDT. Further investigation is needed in order to determine whether it has clinical utility in measuring outcomes of NDT intervention with children who have CP.

### **Finding 2.14.9**

Goal Attainment Scaling is a widely used, well tested, reliable and valid, paediatric intervention outcome measure of small functional changes in a wide variety of daily tasks and it is considered to be an effective long term monitoring tool for children with CP. In addition, it can be used when no other suitable standardized measure is available for these children. Further investigation is needed in order to determine whether GAS can be used to scale meaningful and relevant NDT outcomes.

**Finding 2.14.10**

Functional improvements are more likely to occur with children whose parents identified their goals. Other benefits of parental involvement in intervention were carryover and practice at home, and confidence in their abilities to help their children.