**NDT WORLDWIDE**

# NDT in the United States

## Changes in Theory Advance Clinical Practice

*By Janet M. Howle, PT, MACT*

Advances in the clinical practice of Neuro-Developmental Treatment (NDT) have occurred as NDT evolved under the leadership of the Bobaths from 1943 to 1990. Since then, NDT therapists worldwide have made conscientious efforts to support clinical experience with scientific inquiry in order to continually improve the care offered by this approach to children and adults with motor impairments. The effort to better define the clinical assumptions and precisely describe the principles of intervention is important in order to develop the evidence base for NDT clinical practice and demonstrate its effectiveness as a leading therapeutic approach for clients with neuropathology.

This paper, first, summarizes some of the significant shifts in thinking and application of NDT principles currently practiced in North America. Secondly, it describes adherence to core concepts that the Bobaths originated, which validates the continued alliance of NDT with the Bobath Approach. These ideas and many others are described in depth in *Neuro-Developmental Treatment Approach: Theoretical Foundations and Principles of Clinical Practice* published by the N. American NDT Association (Howle, 2002).

A new paradigm has resulted from blending new ideas with the original concepts generated by the Bobaths. This is the result of critically examining treatment strategies as they relate to relevant functional outcomes and applying knowledge gained from the motor and behavioral sciences to the clinical practice of NDT.

### NDT CONCEPTUAL FRAMEWORK

A clear conceptual framework is essential for proponents of a particular approach to determine the effectiveness of their clinical practice. (Palisano et al 2004) The Bobaths taught and wrote about the relationships between neuropathology and the effects of that pathology on body structures and functions. This framework still remains the center of the NDT approach; however, advances in understanding the impact of the environment and the persons in it on the motor learning process has broadened NDT's focus, which includes directly addressing a client's personal goals and functions. The conceptual framework of NDT has been updated so that it is consistent with the International Classification of Function (WHO 2001) terminology and can be summarized as follows:

1. Pathology in the central nervous system (CNS) impairs the coordination of posture and movement, produces atypical interactions with other body systems, and directly or indirectly impacts on the functional skills that limit the individual's ability to participate in personal life roles.

2. NDT therapists:

a. Identify system strengths and impairments, functional activities and limitations and participation abilities and restrictions that are relevant to the client's goals.
b. Design intervention strategies that target the system impairments hypothesized to interfere with functionality.
c. Use therapeutic handling along with other strategies in activities and settings that are meaningful in the life of the person.

## ADVANCES IN PRACTICE

To illustrate specific advances that comprise contemporary NDT, this paper reviews five concepts that reflect significant changes based on integrating new knowledge and five additional concepts that demonstrate how ideas from the original Bobath approach have been retained, setting NDT apart from motor control and motor learning approaches.

### Shifts in Thinking

***1. The biggest theoretical advance is that the clinical practice of NDT in North America is currently based on an interactive systems model,*** which emphasizes that control of behavior is distributed among interactive neural and body systems that are spontaneously organized by the task parameters in the context in which the task occurs. NDT no longer uses the reflex/hierarchical model of CNS organization, which positioned the nervous system in the role of the controller and links the development of purposeful movement to the maturation and integration of reflex movement.

An interactive systems model is based on information from dynamic systems theory attributed primarily to Nicoli Bernstein (Bernstein 1967) and the theory of neuronal group selection developed by Gerald Edelman (Edelman 1992). These models emphasize that in order to understand the organization and control of movement, it is necessary to recognize and value the influence of all body systems, the specific task that organizes the various sensory and motor components, and the context—both personal and physical environment—within which the action occurs.

The theory of interactive systems asserts that each system is dependent on the integrity of the others and hence, if one system is damaged, it impacts all other systems. The continuous processing of information based on experiences in age-relevant contexts gradually results in selection and assembly of motor behaviors that are effective, variable, adaptive, and capable of meeting the needs of the individual at a particular point in life. (Howle 2002)

***2. NDT recognizes that the establishment and elaboration of motor synergies is the foundation of typical movement.*** NDT no longer considers synergies to be solely an abnormal characteristic of movement.

Motor synergies, organized in neuronal maps and selected for efficient movement, contain both sensory-elicited and self-initiated postures and movements (Lee 1983; Sporns and Edelman 1993). Individuals spontaneously discover preferred motor synergies consistent with their physical characteristics that are flexible yet stable in the presence of continually changing environmental demands. Variability in motor synergies develops through individual experiences in similar yet distinct contexts, giving rise to uniquely individual characteristics while retaining the same general form across all human motor behavior.

Movement disorders, on the other hand, can be recognized by impaired motor synergies characterized by restricted, limited movement repertories. Individuals with neuropathology begin with limited movement patterns and a nervous system with fewer options to develop variability (Hadders-Algra et al 1999; Hadders-Algra 2000). The repetitive selection from these limited repertoires results in maladaptive, ineffective synergies that are unable to adapt to specific conditions that require altering various components, such as velocity, force, timing, and the sequencing of muscle execution demanded by the task (Bobath 1980; Olney and Wright 2001).

***3. NDT recognizes that motor milestones are age-appropriate behaviors with definable onset arising from on-going interactions of the neural, body and motor systems adapting to the influence of the physical laws of the environment.*** No single system contains the observable, identifiable motor milestone, which is the end product of multiple adaptive systems. NDT does not use a linear model to describe the acquisition and maturation of motor milestones nor does it use motor milestones as the framework for NDT (Bobath and Bobath 1984).

Motor development is considered a multi dimensional progression that occurs throughout the lifespan and motor milestones are the outcomes of that process. There are general patterns in the acquisition and timing of skills during development and loss of some skills with aging (Campbell 2000). These consistencies provide a standard of reference for proficient human motor function and make it possible to identify the differences in individuals, both normal deviations and atypical, maladaptive motor functions (Hadders-Algra 2000).

Neural maturation is seen as only one component in an interactive system model that drives motor development. Of equal importance are the development, maturation, and interaction of other body systems; contextual elements; and experience with specific tasks. Neural and body systems and their subsystems, developing at different rates, share in the expression of the final motor behavior and at various times enhance or constrain the rate of development of particular motor patterns. These patterns, when finally expressed together, are identified as motor milestones (Shumway-Cook 2001). Variables that constrain or support the development of motor milestones include muscle strength and length, postural control, perceptual capabilities, interest and motivation, body morphology, and the broad experiences within specific environments (Thelen 1985, 1998; Heriza 1991).

***4. NDT recognizes that problems in tone, posture, balance, and movement are equally important in producing atypical synergies that interfere with functional activities.*** Abnormal tone is no longer considered the dominant neural impairment that leads to abnormal movement as initially described by the Bobaths.

The Bobaths recognized that tone is more than a mechanical property of muscle and reflects the CNS's ability to maintain posture while adapting for movement (Bobath and Bobath 1952). This was an important advance in thinking. However, the Bobaths classified tone as a component of the "postural reflex mechanism," which they considered to be the background for coordinated movement. This led them to assume that abnormal qualities of tone brought about abnormal movement (Bobath and Bobath 1952; K Bobath, 1959).

NDT now recognizes that multiple neural and non-neural systems contribute to the "stiffness" described as the tone of a muscle or group of muscles. This term applies to the adaptability or resistance to motion, which can be felt both while muscles are at rest and while movement occurs. The variable tension or resistance needed to counteract gravity for orientation and stability is often called postural tone. Normal tone changes instantaneously, adapting to the movement requirements dictated by the task parameters. Many researches acknowledge that abnormal muscle tone is a significant finding in persons with CNS dysfunction without implying a relationship to specific movement problems. (Prechtl 2001; Bartlett and Piper 1993). Currently, NDT acknowledges that abnormalities in tone are only one contributor to atypical and ineffective postures or movement sequences.

***5. NDT recognizes that it is essential to evaluate measurable changes in functions as well as changes in motor and body systems that support those functions.*** This objective data helps establish evidence-based practice, evaluate the effectiveness of NDT, and provide clients with available evidence to make informed decisions about their treatment options.

From the beginning the Bobaths were interested in “effective treatment,” but their criterion was the immediate improvement in the quality of movement of each client in response to the therapeutic intervention (Bobath and Bobath 1984). They did not do any original research or collect data in ways that could offer the medical and scientific community evidence for the effectiveness of this popular approach.

However, with the continuing widespread influence of NDT in today’s climate of accountability to clients and their families, professional responsibility mandates that we move beyond empirical appropriateness. This begins with recording objective observations and then submitting what we believe about our observations to the rigors of experimental research in order to know which interventions work, for whom, and under what conditions (Brown and Burns 2001).

Currently, studies of the effectiveness of NDT have reported inconsistent findings and there is still is no body of evidence that is sufficiently comprehensive or rigorous enough to result in empirical consensus or to show that NDT has more value than other methods used by therapists (Butler and Darrah 2001; Sharkey 2001; Tsorlakis et al 2004). NDT therapists do use the available evidence that approximates the client’s characteristics, apply a therapeutic intervention consistent with current NDT principles and practice, and use the most valid results in outcome dimensions that are meaningful to the client (Howle 2002).

## REINFORCING THE BASICS OF BOBATH

Even as NDT has evolved, it retains many of the Bobath’s original concepts. Five concepts which can be credited to the Bobaths and remain core concepts of NDT are summarized here.

1. Perhaps the biggest contribution that the Bobaths made is an understanding of the importance of therapeutic handling as a key intervention strategy. Early on, NDT treatment strategies consisted almost exclusively of hands-on facilitation of movement sequences while at the same time inhibiting those patterns felt to either interfere with efficient actions or contribute to the development of secondary impairments. **Currently, NDT clinicians consider that therapeutic handling, including facilitation and inhibition used in conjunction with motor learning and motor control strategies, makes posture or movement easier or more likely to occur.**

The judicious and precise use of therapeutic handling as a treatment strategy differentiates NDT treatment from any other approach to the management of sensorimotor dysfunction in individuals with neuropathology. NDT attaches importance to the belief that frequent selection of maladaptive motor synergies delays functional recovery, forces compensatory strategies and contributes to secondary impairments or deformities (Howle 2002; Ryerson and Levit 1997). Motor learning (or relearning) requires both physical guidance and independent experience with self-directed tasks to provide clients with opportunities to develop their own motor solutions. For these reasons, therapeutic handling used in NDT requires planning and practice so that it does not interfere with the client’s active attempt to solve motor problems, but guides his selection of the broadest adaptive synergies as the person learns or relearns independent functions.

2. The Bobaths originally focused on the “positive” signs of CNS pathology—spasticity, excessive co-contraction, impaired muscle synergies, and timing and sequencing impairments. They did acknowledge, but gave much less significance to, negative signs, such as weakness, hypokinesia, or impaired motor control. **Now, NDT focuses both on “positive” and “negative” signs of neuropathology when hypothesizing causes of motor dysfunction, recognizing that either may be a major constraint on function.**

For example, in the last 10 years, new findings reflect the awareness that weakness, either as a neuromuscular or musculoskeletal impairment, may be a more important

factor in impaired functional performance than spasticity or other positive signs (Campbell 2000b; Carr and Shepherd 2000). Research suggests a relationship among muscle strength, recovery of function in selected muscle groups, and functional outcomes in individuals with CP and stroke. (Andrews and Bohannon 2000) Various studies have evaluated the role of strengthening programs in improving speed and magnitude of force production, range of motion, and endurance (Diamano 1998). However, the inability to generate sufficient levels of force is only one impairment that impacts on overall function (Palisano 2004).

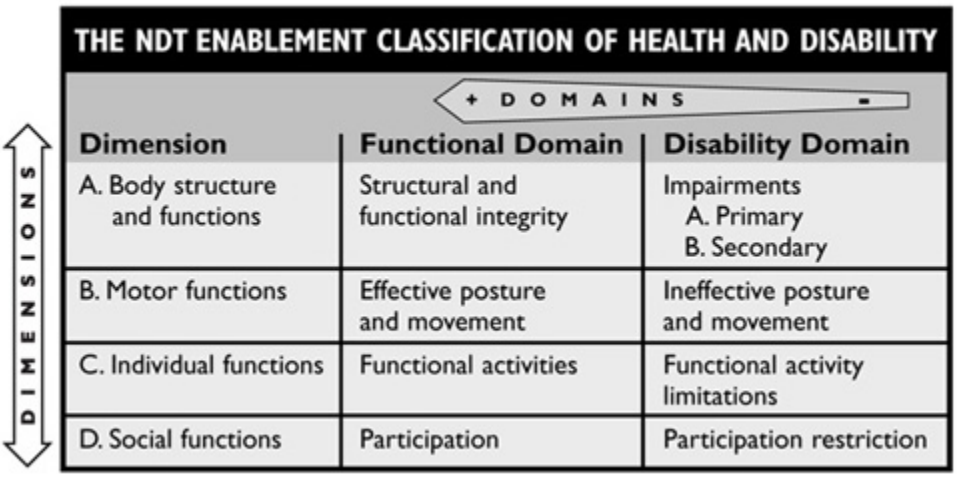
3. During the time of the Bobaths' teaching, enablement models did not exist as we know them today, however, Mrs. Bobath understood and taught the importance of the relationship between impairments, functions and participation in life's roles. **NDT has expanded on these interrelationships and places them in an enablement model based on the ICF taxonomy, adding a 4th dimension—Motor Functions—to focus on the importance of effective and ineffective posture and movement that links functional limitations to system impairments.**

Acceptance of the ICF framework is in keeping with the problem-solving process used in NDT. The NDT enablement model proposes that pathology or dysfunction in the CNS or other body systems affects the individual's ability to solve motor problems. This in turn affects the overall function of that individual in society. Analysis of the complex relationships of various dimensions of health in a model of enablement allows the NDT clinician to classify movement disorders as they affect the individual's life, develop strategies for client examination, implement treatment, and measure outcomes relevant to specific health dimensions (Howle 2002; Palisano 2004; Campbell 2001).

4. In assessment and treatment, Mrs. Bobath developed and taught a problem-solving process which encompassed the whole person: observe what the client does, record how the client does it, and hypothesize why the client does it. **Today, NDT continues to recognize that the best way for a client to improve function is for the therapist, with the client and family, to identify, prioritize, and treat the impairments or limitations in all health dimensions hypothesized to restrict performance.**

NDT continues to attend to motor and system impairments in intervention strategies, emphasizing that the way in which activities are performed is key to developing or improving functionality. The focus on underlying impairments is distinct in NDT and separates it from other approaches that stress practice of function (Ketelaar 2001; Carr and Shepherd 2000). First, NDT examination identifies functional skills and their limitations. Second, evaluation looks deeper, analyzing and prioritizing the effectiveness of the client's posture and movement on those functions. This leads to the formulation of hypotheses that relate neural or body system impairments to limitations in function. These systematic steps establish treatment goals and develop intervention strategies commensurate with the individual's current needs, while aiming for the long-term outcome of achieving the best possible inclusion in society.

5. From its inception, the Bobaths identified feedback from sensory input as an




**sensory input is linked to motor output in two different ways: 1) through the activation of sensory systems, anticipating the postural and movement requirements, and 2) feedback from these systems both during and after movement, modulating movement relative to changes in the task requirements.** In real-life situations, functional movement uses feedback and feed-forward simultaneously to respond to the dynamics of the physical world (Bly 1991).

Currently the NDT approach includes the concept of feedforward, or anticipatory control, in which rapid, complex movements and postural reactions require anticipatory sensory information in order to prepare the postural and movement requirements of the task in advance of the motor act. The Bobaths did not specifically describe sensory feedforward, but they did stress alignment and weight shift in anticipation of movement. Currently, therapists structure the task, provide the best alignment prior to motor execution, and may ask the client to recall similar experiences. In this way, the client benefits from perception and memory of an optimal anticipatory position and thus repeatedly links posture and movement for improved functional outcomes.

## SUMMARY

Many changes have taken place which have advanced NDT from the Bobath's time, when the therapist determined the client's problem and directed specific solutions by handling the client to assure quality movement. Now, NDT therapists recognize that self-determination in goal setting and attention to the motor-learning process is more likely to ensure functional changes in everyday life. NDT is well founded in ideas developed and taught by the Bobaths but will continue to advance and be enriched by the emergence of new information from the movement sciences and by a clearer understanding of the process of recovery from CNS pathology. Our understanding of motor control and motor learning has expanded treatment options. Our task remains to continue to collect evidence that supports this widely respected approach.

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***Janet Howle, PT, is in private pediatric practice and is co-owner of Kaye Products, Inc, in, North Carolina, which manufactures adaptive equipment and mobility aids for infants, children, adolescents, and young adults. She can be reached at jhowle2470@aol.com.***

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Nondestructive testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage. The terms nondestructive examination (NDE), nondestructive inspection (NDI), and nondestructive evaluation (NDE) are also commonly used to describe this technology. Because NDT does not permanently alter the article being inspected, it is a highly valuable technique that can save both money and time in product Nondestructive Testing (NDT) is a forward-looking industry experiencing continuous growth. The NDT market was valued at 16.72 billion (USD) in 2019 and is expected to reach a value of 24.65 billion (USD) by 2025, at a Cumulative Average Growth Rate (CAGR) of 6.7% from 2020-2025. With this consistent and stable growth, we want to bring you a list of the best NDT schools recognized across the US for excellence in NDT. If youâ€™re looking for a career in the field of engineering, quality assurance or emerging technology then NDT is a good fit for you.Â  The list features a variety of institutions across the United States and the opportunities they have to offer. From Level I certification courses to 4-year degrees, the program choice is up to you! Nondestructive testing (NDT) ensures the safety and continued operation of equipment and infrastructure across the United States. Often, the use of nondestructive testing equipment is required by U.S. law. For instance, the Federal Aviation Administration (FAA) requires that each of the 200,000+ aircraft in the United States undergoes periodic safety inspections using NDT.Â  Many different federal and state agencies can require NDT testing in manufacturing, transportation, aviation, oil and gas, marine, and power generation. Military equipment is subject to Department of Defense NDT standards, and standards are often based on information provided by independent testing associations, such as the American Society for Nondestructive Testing (ASNT).