The Effects of Neurodevelopmental Treatment Versus Practice on the Reaching of Children With Spastic Cerebral Palsy
Linda Fetters and JoAnn Kluzik


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The Effects of Neurodevelopmental Treatment Versus Practice on the Reaching of Children With Spastic Cerebral Palsy

Background and Purpose. Children with cerebral palsy (CP) are frequently referred for physical therapy, yet the effectiveness of treatment has not been well-documented. In the relatively few available studies, outcomes are divided between support and lack of support for treatment. The purpose of this research was to document and evaluate the effects of a physical therapy program on the reaching movements of children with spastic CP. Subjects. Eight children with CP, 10 to 15 years of age, were treated daily for 5 days with a version of neurodevelopmental treatment (NDT) and for 5 days with practice of reaching tasks. Methods. Changes in movement time, path, and smoothness of reach were quantified and described using kinematic analysis. Results. There were no differences in any of the variables following 5 days of NDT. There was a difference in movement time, but in no other variables, following 5 days of practice. When time in treatment, rather than type of treatment, was the independent variable, the data showed changes. Both movement time and movement units were reduced following 5 days of treatment. Movement time, movement units, and displacement, but not reaction time, were reduced following the completion of both types of treatment. Conclusion and Discussion. The two treatments in combination may be necessary to achieve these results. Alternatively, either treatment type alone, when given for at least 2 weeks, may produce similar results.


Key Words: Cerebral palsy, treatment; Neuromuscular disorders; Pediatrics, treatment; Practice.

Linda Fetters
JoAnn Kluzik
The purpose of this research was to evaluate the clinical effectiveness of aspects of neurodevelopmental treatment (NDT) and practice on the motor skills of children with spastic cerebral palsy (CP). Cerebral palsy is one of the most common neurologic problems of children referred to physical therapists, with children with spastic CP constituting 60% of this patient population. Although NDT is an accepted method of physical therapy practice for children with CP, few data exist to strongly support this approach. In this study, we evaluated the short-term effectiveness of both NDT and practice intervention for the improvement of speed and control of reaching.

Neurodevelopmental treatment is the most commonly used approach to treatment of children with CP. This approach focuses on encouraging and building upon normal movement patterns and normal postural reactions, while trying to reduce abnormal movements. These treatment outcomes are supposed to be achieved through physical handling of the child during movement, giving the child more normal sensorimotor experiences. As the child gains postural control, the therapist gradually withdraws support. Handling techniques and treatment activities undergo continual change as they are adapted to the responses of a particular child. Traditionally, it has been implicit in NDT that improved postural control will lead to improvement in functional skills without necessarily working on those specific skills. More current interpretations of NDT include the importance of functional skill practice in treatment. The NDT method used in this study combines treatment of postural control and the functional skill of reaching.

Although NDT is widely used by pediatric therapists in the treatment of children with CP, there is little research evidence regarding its efficacy. This lack of scientific evidence of treatment effectiveness is true not only of the NDT approach but for many types of physical therapy for children with CP. Studies of treatment effectiveness in children with CP have varied in research design, selection of subjects, measurement tools, and amount and type of therapy provided. Early studies tended to be descriptive in nature, whereas recent studies have used more rigorous research designs. Researchers face a large number of inherent difficulties when studying treatment efficacy with this particular population. Research on treatment effectiveness in children with spastic CP has varied in terms of the treatments used for intervention as well as the frequency of therapy provided. Numerous studies have focused on the effectiveness of a neurophysiological-based treatment approach, many of which incorporate NDT principles. Some of these studies have shown that...
therapy with an NDT or neuropsychological approach to treatment is effective in improving some measure of motor performance in children with CP. In contrast, some researchers have found little or no change in motor performance to indicate that therapy with a neuropsychological approach is effective. Noonan found an improvement in postural reactions in only three out of seven subjects following a period of "training." A recent study of the effectiveness of NDT demonstrated no improvement in motor performance and showed a decrement in both motor and mental performance following 6 months of NDT compared with 6 months of infant stimulation.

Meta-analysis offers a method of studying the cumulative results of a number of studies focused on a specific area. In an excellent review of research of the effectiveness of NDT in children, Ottenbacher et al. performed a meta-analysis on studies involving the treatment of children with developmental disabilities or delay. Five criteria had to be met for studies to be included in the meta-analysis. One requirement was that statistical tests had to be sufficient to compute an effect size between treatment and no treatment. Nine studies out of those described in the reviewed research reports met the set criteria, and in those nine studies, greater improvement in the motor area was found in children who had received treatment that utilized NDT techniques in comparison with control subjects. Six of the nine studies analyzed focused on children with CP. The authors concluded that the overall effects of NDT were positive, although small.

A finding of little or no change in motor skills may represent a gain from treatment in older children with spastic CP. Such children are at high risk for developing increasing contractures and deformities, as they tend to assume stereotypic postures and move in stereotypic patterns. Without intervention, they may develop muscle contractures and soft-tissue and joint deformities. These contractures and deformities may make movement even more difficult and eventually lead to a decrease in motor skills. This is an important factor to consider when trying to judge the effectiveness of treatment for children with long-standing motor problems.

The repetition of movement, which we will call "practice," is a fundamental component of any physical therapy approach. Although not always explicitly stated, practice is at least implicit within NDT (see Goodgold-Edwards for a proposed application of motor learning principles to NDT). Practice of motor tasks is explicitly manipulated within a motor learning approach to movement or therapy. Although most research in motor learning has been conducted with nondisabled adults, the principles gleaned from this research may be applicable to the therapeutic setting. Motor learning approaches are concerned with how practice affects both performance of a movement task (short-term gain) and retention of the motor skills involved in the task (learning). The variables that affect performance that are measured during or immediately after practice may not continue to show improvement when measured later, after practice has stopped. Thus, the performance of the movement when measured during therapy may not equate to the learning of that movement for use later in the home or community.

Lee et al. have defined movement repetition as being fundamental to the learning of motor skills, yet it is apparent from motor learning research that practice alone does not guarantee learning. These authors suggest that movement repetition actually provides practice at constructing an appropriate action plan for the task. Thus, it is not necessarily the precise rehearsal of muscle patterns or joint combinations that is important in practice, rather it is the construction of a plan of action given the constraints of a particular task that is important. The playing of computer games that require reaching to activate a switch may elicit a variety of movement patterns that have varying degrees of success, as measured by completing the game or beating an opponent. Practice may assist learning by narrowing the field of useful and efficient action plans to successfully complete a functional movement.

The use of feedback during therapy is common in therapy sessions, yet the way in which feedback is given may be crucial to the generalizability of therapeutic gains. Feedback given after every trial may actually be detrimental to learning in comparison with feedback given less often and in a summary format.

There is general agreement that movement must be practiced in order to become a part of a movement repertoire, yet the neurological approaches to treatment of children with CP have not emphasized this critical feature of movement acquisition.

A major difficulty in studying the effects of treatment of motor problems resulting from CP is the lack of methods that are sensitive enough to detect changes in motor ability in standardized tests or typical clinical examinations. This consideration is particularly important with older children. Such changes in motor function may be in terms of efficiency of movement or quality of movement. The measurement tool used to evaluate motor problems may affect conclusions drawn from a study. The tool used must be appropriate and sensitive enough to detect changes.
Most studies of treatment effectiveness have used some type of motor skill or functional skill checklist to measure motor performance.6,14–17,21,22 Changes in motor performance following treatment may involve increments of progress within a skill category, such as changes in quality, ease, smoothness, accuracy, speed, or efficiency of movement. Progress of this nature, however, might not be evident on a skills test. Older children with spastic CP are particularly likely to exhibit a change in quality of movement as opposed to acquiring new functional skills.6 Measuring quality of movement is difficult, and there is a lack of objective measurement tools in this area.13 Therapists often use observation to assess quality of movement, but objectivity, accuracy, and repeatability are limited.

Kinematic analysis offers a means of studying components of a movement in an objective, quantifiable way and is able to detect small changes in movement.30,33 Kinematic data describe movement irrespective of the forces causing the movement.34 Movement is described in terms of position and the derivations of position, such as velocity and acceleration. Thus, if reaching is the movement under study, the exact position of the wrist, elbow, and shoulder in three-dimensional space could be specified as well as the rate at which these points change and the angles of the joints as the movement occurs.

**Movement Units**

Kinematic variables include time, shape of the movement path, velocity, and acceleration. Changes in control of movement may result in a shorter reaction time and overall duration of reach. As movement becomes smoother with improved muscle coordination, it may be reflected in the velocity and acceleration profiles, that is, in movement units.

The concept of a movement unit has been described as the portion of a reach between one acceleration and one deceleration55,56 or the portion of the reach between subsequent points in a curvature-speed relationship.55 Both methods enable systematic description of the stop-start or jerkiness of a reach. Infant reaches initially include multiple movement units, with the number of movement units decreasing with maturity. As reaching patterns mature, the first movement unit accounts for an increasing percentage of the total duration of the reach.55 The jerky stop-start action gives way to one smooth, continuous acceleration, followed by a single deceleration. A mature reach includes a single movement unit with only one stop-start action, suggesting that a lower number of movement units reflects greater control of the reaching movement. Thus, counting the number and relative timing of movement units may offer a useful measurement of change of control or coordination.

In our preliminary study of five preadolescent children with CP, we compared reaching for a target before and immediately after a single NDT treatment.30 The subjects, aged 7 to 12 years, had moderate to severe spastic CP but normal intelligence. They were asked to reach repeatedly to touch a target placed in front of them at the midline. Each subject participated in one testing session during which performance of the reaching task was recorded immediately before and following a 35-minute NDT-oriented therapy session. A single wrist point represented the movement of the arm in space. All sessions incorporated handling techniques that altered muscle tone during movement and facilitated appropriate weight shifting and postural reactions.

Subjects averaged 3.7 movement units before treatment, and the average duration of reach was 1,692 milliseconds. By comparison, age-matched control subjects without neurological impairment performed this movement in 300 to 600 milliseconds and with a single movement unit (Fetters L, unpublished work). The straightness ratio (the distance the hand traveled compared with the shortest distance to the target) was 1.2. Following treatment, the number of movement units decreased to 2.7 and average duration decreased to 1,267 milliseconds (both findings were statistically significant). The duration of the first movement unit in relation to the entire duration of the reach was greater following treatment. This finding indicates that the reach was becoming characterized by a single movement unit (a single stop-start action), which is typical of mature, well-controlled reaching movements. The length the hand traveled (straightness) and the extent to which associated reactions occurred did not differ after treatment.

This article presents the next logical step in this research program. We used the same operational definitions in a short-term controlled study in which the effects of NDT and practice were studied. We expected that NDT, as applied in this research, would assist in improvement of speed and control of movement, as defined by our measures. Reaching and the postural support necessary for reaching might carry over into a functional task such as sitting in front of a computer and reaching to activate the computer and thus were the focus of treatment. Our measures had supported a change following NDT in our previous research, but change over a more extended period had not been measured. We chose an experimental task that was functionally important for the subjects, namely working with a computer. Because our subjects use computers for communication, schoolwork, and entertainment, it was important for them to improve their performance of this task. Our practice intervention...
was designed to allow the subjects to repeat the movement necessary for the task and to assess whether this repetition alone was effective in making change in the dependent measures.

The purpose of our study was to investigate the following research questions: (1) Does 5 days of either NDT or practice improve the reaching characteristics of children with spastic CP? and (2) What is the effect of a period of 5 days with no treatment? We hypothesized (1) that following NDT or practice, reaches of children with spastic CP will be smoother and faster and the time to initiate the movement will be less than prior to treatment and (2) that following a period of 5 days of no treatment, effects of treatment will be sustained.

**Method**

**Subjects**

Eight children (2 female, 6 male), aged 10 to 15 years, with spastic quadriplegic CP participated (Tab. 1). This age range extended the ages of the subjects in our previous study, and the number of subjects increased the sample size. Subjects were recruited from the Cotting School, a private school for children with physical disabilities in Lexington, Mass. Subjects were included if, according to their therapist and classroom teacher, they (1) were able to understand and carry out spoken directions included in the reaching task, (2) had sufficient visual skill to localize an object with both eyes, (3) had sufficient passive range of motion to be able to reach the target used in the reaching task, and (4) used computers in the classroom or for schoolwork so that improvement would be functionally useful. Ten subjects were originally tested in the project, but only 8 subjects had sufficient data to be included in the analysis. One subject was eliminated from the analysis because he was available for only 2 days of data collection. The other subject who was eliminated from the study was unable to complete most of the sessions because of fatigue. The children and their parents signed informed consent forms approved by the Institutional Review Board at Boston University and the Cotting School.

The project took place at the Cotting School. A kinematic laboratory was set up in a room adjacent to the physical therapy department at the school. In this way, subjects participated daily at their school with minimum inconvenience. This arrangement was essential to the successful completion of this study.

**Instrumentation**

Reaching movements were recorded using the WATSMART (Waterloo Spatial Motion Analysis and Recording Technique) motion analysis system. The WATSMART is a valid and reliable system for reproducing human movement. The reliability values for reproducing a fixed target length (ruler) rotated in three-dimensional space in our laboratory were below 2 mm. This finding means that the WATSMART system reproduced absolute length of the moving ruler with errors of 2 mm or less. The WATSMART was calibrated before every data-collection session using 22 infrared light-emitting diodes (IREDs) from the calibration frame at a sampling rate of 100 Hz. The average error of calibration ranged between 0.7 and 2.7 mm over the entire project period. The tabletop, the computer, and in some cases the chair were covered with an infrared absorbing cloth to minimize reflections. The setup for calibration was kept constant for data collection.

An IRED was attached to the arm used for reaching. The IRED was taped to the skin over the styloid process of the ulna. This limb point was used to represent the arm in space. Two cameras, which were sensitive to the infrared light spectrum, recorded the position of the arm at a sampling rate of 100 Hz. Infrared cameras were fixed to a steel bar mounted across the laboratory. In this way, the camera mounting was rigid and not susceptible to being moved, because moving the sensors after calibr-
tion would require recalibration of the system. Cameras were placed with the lines of sight of the lenses forming a 65-degree angle. The skin under the IRED was marked with permanent ink so that the IRED could be placed on exactly the same place for each of the daily sessions. The position of the IRED during each reach was stored as numerical coordinates, which were later converted to three-dimensional numerical values. A Hewlett-Packard Vectra computer\(^1\) was used for collection, storage, and analysis of the positional data. Data missing as a result of obscured IREDS were interpolated only if not more than 5% of the total reach was missing in a continuous segment. This interpolation rule resulted in a loss of approximately 20% of the data.

The decision of how to handle missing data is specific to each laboratory. Obscured data points are always a problem with kinematic data, particularly in the collection of three-dimensional data, where two cameras must view each IRED in order to reconstruct the movement. We have chosen a very conservative approach by not interpolating if more than 5% of the data are missing in any one section of the reach. Our interpolation algorithm uses data points from before and after the missing data. The more data there are both before and after the missing data, the better the estimate will be. In gait data, multiple cycles are usually available in order to make the missing data-point estimates. In a noncyclical movement such as reaching, the data available for estimates are more limited in any given trial. Consequently, estimates are based on fewer data. The biggest problem with this type of decision rule is that a particular class or type of movement may be eliminated from study, restricting study to movements only with certain characteristics. These characteristics may cause obscuring of the IREDS.

**Procedures: Pretest-Posttest Tasks**

Subjects played an interactive video game (Zigzag\(^1\)) on an Apple Ile computer\(^2\) before and after each treatment session. The computer game was activated via a light-touch switch (LTS), as many subjects did not have the control to hit the appropriate computer key. Subjects started with their hands on an LTS located in front of them on the tabletop (Fig. 1). The therapist playing the video game with a subject pressed a second LTS simultaneously with a “go” verbal signal for the subject to start. The subject lifted the hand from the tabletop LTS and hit a third LTS positioned at the top of the computer screen, which changed the picture on the computer screen, adding colored lines of varying lengths to the screen. The goal of the game was to fill the screen, and this goal was motivating for the subjects. Zigzag has no time component; thus, there was no time pressure for movement. In addition, there was no wrong response. The change in voltage of the LTS was recorded via the WATSCOPE, an analog-to-digital converter that is synchronized with the WATSMART. In our previous research, we used a touch-to-target task, which proved boring after repeated trials for most subjects. Interacting with a computer was fun and thus more motivating.

Subjects were seated in their wheelchairs or on an appropriately sized straight-backed chair in front of the table. Choice of seating was determined by the typical seating used by each child for computer work. Seating had been determined by the school’s occupational therapist or physical therapist in most cases. The LTS that activated the computer was located so that each subject easily touched the pad when the subject’s arm was passively extended; thus, the target distance was scaled for each subject. Each child performed a minimum of 10 trials of the reaching task using the preferred hand.

**Dependent Variables**

**Movement unit.** Smoothness was defined as the number of movement units per reach. A movement unit is the portion of the reach between one acceleration and the following deceleration. An acceleration and a deceleration are defined by a rate of change in velocity of greater than 5 mm/s\(^2\).

**Movement time.** Duration was determined by the interval between tabletop LTS liftoff and computer-screen LTS touch.

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1 Hewlett-Packard Co, 3000 Minnerrman Rd, Andover, MA 01810.
2 Don Johnston Developmental Equipment Inc, PO Box 639, Wauconda, IL 60084.
3 Apple Computer Inc, 20525 Mariana Ave, Cupertino, CA 95014.

![Figure 1. Laboratory setup. C1 = camera 1, C2 = camera 2, VC = video camera, C = computer, S1 = tabletop switch, S2 = computer switch.](http://ptjournal.apta.org/Downloaded from http://ptjournal.apta.org/Downloaded from http://ptjournal.apta.org/)
Path. Straightness, or total displacement, was defined as the length of path of the reaching movement between liftoff and computer-screen LTS touch.

Reaction time. Reaction time was the time interval between the signal from the second LTS (activated by the therapist) and the signal from the tabletop LTS indicating liftoff of the hand (beginning reach).

Treatment Conditions
Treatment took place in the physical therapy department, which was adjacent to the laboratory. Subjects were assigned to each of two treatment conditions, NDT and practice, with the order of the two treatments counterbalanced. Slips of paper with “NDT” and “Practice” written on them were placed in a hat, and one slip of paper was drawn. The first subject was assigned to the NDT condition, with subsequent subjects alternately placed in the two treatment conditions. This procedure was followed for all 10 subjects who entered the study. Only data for 8 of the 10 subjects are reported here. Five subjects were assigned to the practice condition first and to the NDT condition second; 3 subjects were assigned to the treatment conditions in the opposite order. A no-treatment condition occurred for 1 week between the two treatment conditions. Treatment conditions consisted of five daily sessions of physical therapy for 35 minutes each session. Our previous research demonstrated changes after one session of NDT. We were interested in exploring the effects of treatment after 5 days in order to observe any continued effects of treatment before designing a longitudinal study. Session length was kept to the typical length of treatment during the school day. The subjects received no therapy for 1 week prior to the first treatment session. Another no-treatment week occurred after the first 5 days of treatment and prior to the second 5 days of treatment. With this design, all subjects received both treatments and experienced two no-treatment weeks.

Each day of the study, we measured reaching movements before and after treatment. In our previous research, we measured the effects of treatment only immediately after one treatment session. By recording the movement immediately after treatment and then before treatment on subsequent days, we measured the treatment effects over time. If treatment did not have effects after the first day, this design enabled us to ascertain when, during the 5-day period of daily treatment, effects might be seen. In addition, the week of no treatment followed by measurement provided an opportunity to measure retention of any improvement demonstrated in the first week of treatment.

The NDT sessions were provided by the second author (JK), a physical therapist certified in pediatric NDT. Although treatment activities varied for each subject, overall goals were the same for all subjects. Goals included improved trunk and shoulder-girdle control during reaching, improved smoothness and efficiency of movement, and improved ability to initiate movement (Appendix).

The practice sessions were also provided by the second author and consisted of repeated reaching to play computer games. During practice, the children could choose from a menu of eight computer games. In each game, the subjects were required to reach to play the game in a way similar to the reach to be measured. The therapist played the computer game with each subject to provide motivation and encouragement, but no feedback about the movement was given. Instead, comments were made occasionally about the subject’s video game performance (eg, “You beat me again” or “This is a fun choice”). Although these practice sessions had components of motor learning, they did not strictly adhere to a motor learning framework. Feedback was not planned or manipulated in any systematic way, although to be consistent with the motor learning literature, we restricted feedback about the movement. The amount of practice within a session was controlled by the choices of games made by the subject.

Data Reduction and Analysis
Digitized data were filtered at 5 Hz using a third-order Butterworth filter with forward and reverse passes. The resultant value for the wrist point and the target were computed from the three-dimensional filtered data. The resultant value was used to represent the wrist point in space. The remainder of the IREDs were used for subsequent analyses. Dependent measures were taken from the resultant values of the wrist point over time. Prior to computing means for the pretest and posttest sessions for each subject and each day, a repeated-measures (day×trial) analysis of variance (ANOVA) was performed. There were no main-effect or interaction-effect differences between trials or days for any of the variables. This finding indicated that trials for any given day could be estimated with a mean score, because they were not different. As a consequence, mean values were computed for pretest and posttest scores for each subject and each day. Change scores for resultant values were computed by subtracting the posttest mean scores from the pretest mean scores for all trials each day. Change scores were then used for the statistical analyses of the dependent measures. A positive change score indicated a decrease in amount of the variable after treatment (ie, improvement), whereas a negative change score indicated an increase in amount of the variable after treatment (ie, worsening).
Table 2. Means, Standard Deviations, and Ranges of Change Scores for All Subjects for All Dependent Measures by Day

<table>
<thead>
<tr>
<th>Day</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
</tr>
</thead>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>-0.04</td>
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</tr>
<tr>
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<td>-0.40 to 0.15</td>
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<td></td>
<td></td>
<td></td>
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<td>0.24</td>
<td>-0.02</td>
<td>0.21</td>
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<td>0.23</td>
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<td>-0.46 to 0.52</td>
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<td></td>
</tr>
<tr>
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<td>-21.30</td>
<td>5.74</td>
<td>-30.48</td>
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<td>70.43</td>
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<td>-77.92 to 33.47</td>
<td>-142.86 to 308.05</td>
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<td></td>
</tr>
<tr>
<td>X</td>
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<td>2.10</td>
<td>0.67</td>
<td>2.06</td>
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<td>1.90</td>
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<td>Practice</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>-0.13</td>
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<td></td>
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<td></td>
<td></td>
</tr>
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<td>81.53</td>
<td>68.80</td>
<td>49.63</td>
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<td>-109.0 to 100.98</td>
<td>-86.75 to 67.56</td>
</tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td>1.30</td>
<td>-0.20</td>
<td>0.02</td>
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<td>1.20</td>
<td>2.80</td>
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<td>-0.86 to 5.50</td>
<td>-1.33 to 1.47</td>
<td>-2.89 to 6.00</td>
</tr>
</tbody>
</table>

*RT = reaction time, MT = movement time, path = total displacement, MU = number of movement units.

For various reasons (e.g., sickness, death of a family member, school events), none of the subjects completed 5 full days of treatment during either treatment week. Thus, the terms "first day" and "last day" rather than the terms "day 1" and "day 5" are used for analysis. Data were analyzed using an ANOVA for repeated measures and paired t tests. All statistical tests for this project were performed with SAS software on an IBM RS/6000 mainframe computer.

The alpha level was .10 for all statistical tests. This choice was made to avoid a Type II error, that is, assuming that no difference exists when a difference actually does exist. This level of significance is a reasonable choice with a small sample size such as that of our study and in light of the data that will be presented.

**Results**

**Does 5 Days of NDT or Practice Improve the Reaching Characteristics of Children With Spastic CP?**

There were no differences between days for change scores of reaction time ($F=0.83, df=3$), movement time ($F=1.59, df=3$), total displacement ($F=1.10, df=3$), or number of movement units ($F=0.91, df=3$) for NDT. Means and standard deviations for the change scores of all subjects, by day, for all variables in the NDT condition are presented in Table 2. The grouped means and standard deviations, by day, for the NDT condition are graphed in Figure 2.
There were no differences between days for the change scores of reaction time ($F=0.95, df=2$), movement time ($F=0.78, df=2$), total displacement ($F=1.10, df=3$), or number of movement units ($F=0.48, df=3$) for practice. Means and standard deviations for change scores of all subjects, by day, for all variables in the practice condition are presented in Table 2. The grouped means and standard deviations, by day, for the practice condition are graphed in Figure 3.

The first-day pretreatment values were then compared with the last-day posttreatment values for each of the variables in the NDT condition. These values are graphed in Figure 4. For example, the pretreatment means after the first day of NDT were compared with the posttreatment means of the last day of NDT. This comparison is equivalent to computing a weekly change score. There were no differences for the variables of reaction time, movement time, total displacement, or number of movement units for the NDT condition. The first-day pretreatment values also were compared with the last-day posttreatment values for the practice condition and are graphed in Figure 5. There was a difference for movement time ($P<.05$) but no difference for reaction time, total displacement, or number of movement units for the practice condition. There was a decrease in every variable (except reaction time) for each treatment week; however, only the decrease in movement time proved to be statistically significant, even though the alpha level of .10 was used. The decrease was consistently larger for all variables in the practice condition than in the NDT condition.

**What Is the Effect of 1 Week With No Treatment?**

The posttest scores for the last day of week 2 (end of the first treatment) were compared with the pretest scores for the first day of week 4 (start of second treatment). This analysis allowed us to measure the change after 5 days of treatment coupled with 1 week of no treatment. Means and standard deviations for the pretest-posttest scores for all variables are graphed in Figure 6. There was a continued decrease in the values for all variables, with the exception of reaction time, which remained unchanged.
Because our original hypotheses were not supported but variables appeared to change, we decided to ask our questions slightly differently. That is, perhaps the type of treatment is less important than the overall amount of time the treatment is given. Thus, we asked: What is the effect of amount of treatment on the reaching variables? The pretest and posttest scores from the beginning to the end of the first treatment (week 2) and also for the second treatment (week 4), regardless of nature of treatment, were compared. This analysis addressed the question of time in treatment rather than the nature of the treatment. The means and standard deviations for all variables are presented in Table 3. At the end of the first week of treatment (three subjects had NDT and five subjects had practice during this week), there was a difference for both movement time ($P<.05$) and number of movement units ($P<.05$). There were no differences for total displacement or reaction time, although the change in both of these variables showed an improvement (total displacement, $P=.12$; reaction time, $P=.14$). There were no differences in any variables after week 4 alone. Inspection of the data in Table 3 reveals the major change in variables occurred during the first week of treatment. During the second week, these changes were maintained or slightly improved.

When the means of the pretest values for the first day of the study were compared with the means of the posttest values for the last day (ie, beginning of the study compared with the end of the study), there was a difference for movement time ($P<.05$), total displacement ($P<.10$), and number of movement units ($P<.01$) but not for reaction time ($P<.12$). The data are graphed in Figure 7.

**Discussion**

Improvement in the variables under study was not apparent after 5 days of either NDT or practice. The original finding, that these same variables improved after one session of NDT, was not supported in this extended study. This finding may be due to the large variability of response or to an insufficient amount of treatment time. The NDT or the practice given over the entire treatment period may have achieved the improvement in the variables that was seen in this study. It is not possible to ascertain whether 2 weeks of either treatment or both treatments together produced the measured improvements. What is clear is that measuring at the end of the study, rather than the end of each treatment condition, was essential for recognizing change in these variables. A future study should increase the amount of time that each treatment is given. Weekly measures over multiple weeks might provide the necessary data to sort out the importance of the type of treatment that is most effective for change in these variables. The analysis of the first week of treatment suggests that there may be at least two, and we think perhaps many more, ways to improve a motor skill when treatment is offered with sufficient frequency. The greatest improvement in all variables occurred at the end of the first week of treatment. These improvements however, lasted through a week of no treatment and throughout the second week of treatment. Although a longer study would be necessary to be certain, it may be that once qualitative change has occurred after sufficient frequency of treatment, the change remains. This would be considered learning within a motor learning approach.
Table 3.
Means and Standard Deviations by Week From First Day to Last Day

<table>
<thead>
<tr>
<th>Treatment Week</th>
<th>Reaction Time</th>
<th>Movement Time</th>
<th>Movement Unit</th>
<th>Total Displacement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>SD</td>
<td>X</td>
<td>SD</td>
</tr>
<tr>
<td>Week 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>1.00</td>
<td>0.55</td>
<td>1.69</td>
<td>0.84</td>
</tr>
<tr>
<td>Day 5</td>
<td>0.72</td>
<td>0.23</td>
<td>1.02*</td>
<td>0.35</td>
</tr>
<tr>
<td>Week 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Day 1</td>
<td>0.69</td>
<td>0.35</td>
<td>0.95</td>
<td>0.36</td>
</tr>
<tr>
<td>Day 5</td>
<td>0.66</td>
<td>0.19</td>
<td>*0.90</td>
<td>0.23</td>
</tr>
</tbody>
</table>

*Asterisk (*) indicates significant difference.

Figure 7.
First-day pretreatment values for first 5-day period of treatment (week 2) compared with last-day posttreatment values for second 5-day period of treatment (week 4) (beginning to end of study).

The improvements in speed and smoothness of movement that were seen in this study were not measured against a clinical or functional scale of movement. Movement times decreased by 30% for some subjects. Summed over the course of a day, this could certainly be a benefit to the child in terms of energy expenditure and classroom work completed. These measures might be a focus of future studies in which performance in a laboratory setting would be matched to classroom performance.

Each type of treatment (NDT and practice) might be expected to yield different changes in motor performance. Because the NDT approach included goals of decreasing spasticity and improving postural stability, it may be that the treatment effects would be most obvious in the postural set used for reaching. Practice of the task might be expected to affect variables such as movement time, which was the case in this experiment. We are currently evaluating the postural alignment and control in these subjects during the reaching task. Results of this analysis may assist us in understanding the differential effects of treatments on different parts of a movement.

The importance of time in our research should be emphasized, both time in treatment and the effects of time off. From the motor learning literature, we have learned the value of rest or time off from practice, yet this is not something that therapists typically include when working to improve functional skills. Future research might concentrate more on the effects of high-frequency treatments coupled with “time off,” which may encourage the consolidation of the motor skill.

One other feature of our research is the variability between subjects and within each subject’s ability. This finding is not new, but analysis and testing of strategies to address this variability are needed. We have suggested elsewhere that subjects might be grouped by movement variables that they have in common rather than by features such as spasticity or body parts involved. We became aware of this possibility more clearly while working on these data. Some children with spasticity may have problems with initiation of movement, whereas others have difficulty with the overall speed of a movement. A new research strategy would be to analyze movement components such as speed, smoothness, cardiorespiratory effort, ability to isolate movement, and so forth prior to treatment and then assign groups for intervention based on these common features of movement. As we outlined in the beginning of this report, the movement problems of children with CP are varied, but children may be grouped based on common features that we have not previously identified.

In future research, additional variables should be assessed following treatment. We had two examples of subjects reporting “tightness” of muscles following their experimental treatment regimen. Five of the subjects experienced 1 week of no treatment followed by 1 week of practice and then another week of no treatment. One subject’s mother indicated that if her daughter had not...
received "real therapy" during the fourth week, she was going to stop participation because she was having so much difficulty helping her daughter put on her shirt in the morning. A second subject reported stiffness in his muscles at the same point in the project. The typical treatment these subjects were receiving was clearly benefiting them in ways we did not measure in this study.

Conclusions
Experimental research on rehabilitation for children with CP is critical for the improvement of our understanding of the nature of change and how it is affected. Although this study was limited by a small sample size and large variability of the children’s movements, we were able to further develop dependent measures that are sensitive to change and features of therapy such as frequency of treatment that should be explored further. The relationship of changeable movement features also must be mapped onto functional abilities. In this study, for example, the improvement in speed and smoothness of reaching may have been accompanied by changes in cardiorespiratory requirements or classroom performance with communication boards. These expanded measures should be included in future research.

References
Appendix.
Neurodevelopmental Treatment-Based Treatment Activities

Improve ability to reach forward and up.

Improve initiation and control of active shoulder flexion with neutral rotation. Increase range of motion between scapula and humerus, strengthen shoulder flexors, and reduce muscle tone or spasticity that may be preventing desired motion.

Improve active elbow extension during a forward reach. Increase range of motion, reduce muscle tone, and strengthen muscles at the elbow.

Improve shoulder and scapular stability during forward reach.

Improve trunk stability and ability to make postural adjustments during reaching tasks so subject can easily reach forward without forward or lateral trunk flexion. If forward or lateral flexion accompanies reaching, then improve ability to regain upright, midline posture.

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Linda Fetters and JoAnn Kluzik

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