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ABSTRACT

Three groups of children aged 8-10 who scored below the 22nd percentile on the PATests were taught basic math skills for 16 hours. One group received individual instruction using Precision Teaching and Direct Instruction, the second group received group instruction using Precision Teaching and Direct Instruction, and the third group received group instruction using a constructivist Recommended Practice approach. All children changed their percentile ranking significantly the following year by up to 60 percentile ranks, with some clear differences according to the method by which they were taught. (Contains 14 references.) (Author/ASK)

I CAN DO MATHS: CHANGING CHILDREN'S MATHEMATICS PERCENTILE RANKING

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I CAN DO MATHS: CHANGING CHILDREN'S MATHEMATICS PERCENTILE RANKING

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Three groups of children aged 8-10 who scored below the 22nd percentile on the PATests were taught basic maths skills for 16 hours. One group received individual instruction using Precision Teaching and Direct Instruction, the second group received group instruction using Precision Teaching and Direct Instruction, and the third group received group instruction using a constructivist Recommended Practice approach. All children changed their percentile ranking significantly the following year by up to 60 percentile ranks, with some clear differences according to the method by which they were taught.

Lack of achievement in mathematics by school children has been of considerable concern to educators in recent years. (Bateman, 1995; Flockton & Crooks, 1998: Stein, Silbert & Carnine, 1997). One focus of concern has been on the performance of children at the primary level, and claims have been made that the performance of many of these children is not sufficient for them to succeed at secondary school. Factors outside the school have been identified as related to mathematical failure, such as little preschool experience, low language levels, low socioeconomic situations, and culture, but the relationship is not perfect and does not address the role and responsibility of the school for providing adequate instruction for all children (Berlin & Sum, 1988).

Instruction-related factors which affect a child's mathematical performance include the identification of prior knowledge (Carnine, 1980), the explicitness of instruction (Carnine & Jitendra, 1997: Carnine & Stein, 1981), the selection of examples (Trafton, 1984), the opportunity to achieve fluency in the new skill (Lindsley, 1992), and the structure of the manipulative activities (Carnine & Jitendra, 1997).

The identification of prior knowledge refers to the analysis of a mathematics task to determine the skills which must be performed in order to complete the task. The child's performance in each of the component skills is then assessed and those which are not performed to an acceptable level are taught before the task itself is taught. The rationale for this is that performance in component skills needs to be automatic in order for the learner to concentrate his/her attention on the new task to be learned. If the learner's attention is distracted by the performance of component skills, attention will be able to be focussed on the new task, and it will not be learned. Ashcraft (1985) has argued that the automatic retrieval of basic facts is necessary to "free up" the working memory to apply those basic skills to more advanced skills or tasks.

The debate over discovery versus expository instruction continues to this day. The determination as to which should form the instructional method for primary school children depends on the measure of instructional effectiveness used. Early studies using the two instructional methods compared highly-directed discovery instruction with simplistic expository instruction. There is actually a wide range of both instructional methods. A comparison of a direct expository method with less direct methods for teaching a range of mathematics skills to students varying in age and ability, showed that the direct expository method was more effective (Kameenui, Carnine, Darch, & Stein, 1986). Further support for explicit instruction in mathematics skills has been demonstrated with problem-solving (Darch, Carnine, & Gersten, 1989), counting strategies for learning basic facts (Carnine & Stein, 1981), and a variety of mathematics skills (Johnson & Layng, 1992).

The selection of examples used to teach a new skill is critical to successful learning. The examples need to include all relevant variables to enable the student to use the skill in the appropriate situations, and

irrelevant variables need to be included so the student can discriminate when the skill is to be performed (Renaut, 1996). If the relevant variables are not present in the set of examples used to teach a skill, students may be able to perform the skill under some conditions but not others. Students have experienced difficulty renaming in a subtraction problem if the numeral contained zeros, and adding when an addend was 0 (Flockton & Crooks, 1997; Trafton, 1984).

Fluent performance is a further critical factor in the performance of a skill. The "freeing up" of the working memory to perform more complex tasks described by Ashcraft (1985) occurs as a result of fluent performance, fast and accurate performance. This is achieved through Precision Teaching, the repeated performance of a skill for a set period of time, until the performance of the skill occurs at a predetermined high rate (Lindsley, 1992). The achievement of a set rate takes days or weeks to occur, depending on the task. Each day, the rate is recorded on a semi-logarithmic graph or "standard celeration chart" and instructional decisions are made based on the student's performance.

The organisation and purpose of manipulative activities given to students is critical in the performance of a skill given the time taken to perform these activities. Carnine and Jitendra (1997) have identified difficulties in the use of manipulative activities to provide instruction in fractions. In their study of activities in traditional textbooks, they found that the higher acceptance texts had more hands-on activities and many were open-ended. The language in the instructions for the activities presumes good oral reading and comprehension skills, and component skills knowledge.

This study examined the effect of an instructional programme based on the principles of Precision Teaching and Direct Instruction on children at risk of failure in mathematics. This programme was compared with an instructional programme based on the teaching procedures recommended to New Zealand teachers in the New Zealand Mathematics Curriculum and by mathematics advisers in schools. Individual instruction was included to replicate the remediation practices used in primary schools.

METHOD

Subjects

The subjects were 30 boys and girls aged from 8 to 10 years at a decile 7 school of 550 pupils. The subjects were in years 4, 5 and 6.

The age percentile rankings according to the NZCER Progress and Achievement Mathematics Test ranged from 1 to 21.

The subjects in the first two groups were selected by identifying all the children in years 5, and 6 who scored below the 22nd percentile. There were 33 children identified. Of those 31, any children who were on Ritalin or who were ESOL students or who were receiving one-to-one tuition were excluded from the study. The remaining 30 children were randomly allocated to three groups. One group served as a training group for trialing the procedures to be used in the Group Precision Teaching and Direct Instruction teaching method. The remaining two groups became Group 1 and 2 in the study.

The third group was selected the following year from children in years 4 and 5 who had scored below the 22nd percentile. Year 4 had to be included because there were so few children identified from Year 6. Most had been included in the groups the preceding year. There were 24 children identified. Those children who were on Ritalin, who were ESOL students, who were receiving one-to-one tuition, or who had been

involved in the trial the previous year were excluded. One child from Year 6 was included, even though he was on Ritalin (a low dose), to make up a group of 10.

The average age of Group 1 was 9 years 6 months, Group 2, 9 years 1 month, and Group 3, 8 years 5 months.

Settings and Materials

Instruction took place in a regular classroom in the school from 9-9.40 am four days of the week.

During the individual instruction treatment, subjects sat at a desk with a teacher for the whole session. The pairs of desks were arranged throughout the room to minimise visual contact with other pairs of subjects and teachers and reduce auditory disturbance.

During the group Recommended Practice instruction, two seating arrangements were used. For the group instruction, subjects were seated on a large carpeted area in front of a white board with the teacher seated in a chair beside the whiteboard. When the subjects did individual or paired work, they were seated at desks facing the whiteboard or they worked on the carpeted area.

For the group Precision Teaching and Direct Instruction treatment, the subjects were seated at pairs of desks facing each other. During maintenance and acquisition, all chairs faced the whiteboard or some subjects were seated on a mat.

For the Precision Teaching and Direct Instruction treatment, the materials consisted of the following Morningside Mathematics Fluency (1993) books:

Basic Number Skills Volumes 1-2 Reading and Writing Whole Numbers

Volume 3 Place Value, Greater than-Less Than

Maths Facts Volumes 1-3 Addition and Subtraction

Volumes 4-6 Multiplication and Division.

Probes for telling time, naming before, after and between, and the four arithmetic operations were constructed according to the principles of Precision Teaching and Direct Instruction (Renaut, 1996).

For the Recommended Practice treatment, the following textbooks and games were used:

Mathematics in the New Zealand Curriculum, Ministry of Education

School Mathematics 2, 3, and 4, Ministry of Education

Experimental Design

A between-groups design was used to compare the percentile rankings of each group of subjects before the intervention, after the intervention, and at the follow-up measure.

The three group treatments consisted of individual instruction using Precision Teaching and Direct Instruction, group instruction using Precision Teaching and Direct Instruction, and group instruction using Recommended Practice. Each group received one of the treatments which consisted of 32, 40-minute teaching sessions.

A single-subject design was used to compare the percentile rankings of each subject before the intervention, after the intervention, and at the follow-up measure.

Procedure

Assessment

The performance of each subject in the component skills was assessed for accuracy and fluency using a test administered individually to each child by the first two authors and the teachers of Group 1. The skills assessed were:

basic facts in addition, subtraction, multiplication, and division

reading and writing numerals to millions

place value to millions

<, >, = with numbers to 100, and two addends or factors

numbers before, after and between

reading times on an analogue clock

addition, subtraction, multiplication and division arithmetical processes.

From the results of this assessment an individual programme was developed for each child consisting of the next stage of each skill. Where a child was accurate and fluent in a skill to the most advanced stage, that skill was not included in the programme.

Training teachers

Ten experienced early childhood, primary and secondary teachers from a post-graduate special education course which included Applied Behaviour Analysis, Precision Teaching and Direct Instruction, were trained in the use of the specific Direct Instruction and Precision Teaching methods and materials used in the study. This training took place over three one-hour sessions.

The teacher who taught the group instruction in both the Precision Teaching and Direct Instruction treatment and the Recommended Practice treatment had completed the postgraduate special education course two years before, and he attended the three one-hour training sessions. He received an additional individual two hours training in the Recommended Practice treatment. This had been the instructional method taught in his initial teacher training and he had used for thirteen years.

Treatment 1: Individual instruction using Precision Teaching and Direct Instruction (Individual PT/DI)

Each teacher planned the teaching session for his/her student, separating similar skills and providing variation in accuracy and fluency performance and response format. Each session consisted of between six and eight skills.

Initial instruction in a skill was provided by identifying the knowledge form of the skill and providing instruction in the appropriate format (Kameenui & Simmons, 1990). The subject was then given opportunities to practice the skill until 100% accuracy was achieved on three consecutive occasions. Following this, the skill was practiced until a criterion measure of fluency or rate was achieved. The criterion was determined from the manual for the Morningside material, or by assessing the child's performance on a skill similar to the one being taught. The second method was used where the child's speech or writing was of such a rate that the child would not be able to achieve the Morningside criterion. Fluency was measured using a timer set at one minute, 30 seconds, or 10 seconds, depending on the individual child and the skill. The teacher recorded the results on a semi-logarithmic graph and showed this to the student.

Treatment 2: Group instruction using Recommended Practice (Group RP)

The teacher started each session with the whole group on the mat or at their desks and skills which had been taught previously, were revised as a maintenance activity. This was followed by whole-group teaching if the teacher thought it was necessary. This was judged on the subjects' performance during maintenance.

On three days, the group was divided into three subgroups based on the results of the assessment. Each subgroup followed the sequence; teaching, practice and activity, but each group started the day at a different point in the sequence.

Subgroup A	Subgroup B	Subgroup C
Teaching	Practice	Activity
Practice	Activity	Teaching
Activity	Teaching	Practice

During the teaching part of the cycle, the teacher taught the skill for the day. The subjects were given an opportunity to practice the new skill during this time. The subjects continued the practice until the teacher was satisfied that they could perform the skill independently. The subjects then went to their desks to practice the skill using exercises from the textbook. During the activity part of the cycle, the teacher would introduce and demonstrate how to play a game or perform an activity which involved the subjects applying the new skill or skills learned the previous week. The activities consisted of problems to solve by using equipment, short worksheets, or activities in pairs or small groups.

Treatment 3: Group instruction using Precision Teaching and Direct Instruction (Group PT/DI)

Before starting instruction in the targeted skills, the teacher took five days to teach the subjects to use the timer and graph on a semi-logarithmic graph. The teacher started each session with the whole group looking at the board and the skills in which all subjects were accurate or fluent were revised. Those subjects requiring fluency in one of the skills then worked in pairs or individually while the other subjects remained with the teacher for instruction in a new skill (acquisition) or accuracy practice. Initial instruction

in a skill was provided by identifying the knowledge form of the skill and providing instruction in the appropriate format (Kameenui & Simmons, 1990). The subjects were then given opportunities to practice the skill until 100% accuracy was achieved by all of the subjects. The subjects then did fluency practice in pairs at their desks using probe sheets. Fluency was measured using a timer set to one minute. Each student recorded his/her own results on a semi-logarithmic graph. Each student had a folder in which the probes and graphs for the day were placed and the students worked through these in pairs. The teacher moved around the subjects monitoring fluency, helping the subjects analyse their errors, and correcting errors or teaching new skills when the subjects had reached criterion. Each evening, the teacher checked the folders and placed in them new probes and graphs for the skills in which the subject had reached criterion if the student had not already placed the new probes in the folder.

Behavioural Measures

Each subject's performance in mathematical skills was measured using the New Zealand Progress and Achievement of Mathematics Tests (1993). The first test (pretest) was administered in the February in the year in which the treatment was given. The second test (post-test) was administered in the year following the treatment. The third test (follow-up) was administered one year after the post-test.

Reliability

Procedural reliability and recording reliability for Treatment 1 was conducted by the first two authors. Twenty percent of the teaching sessions were observed. The authors each observed one teacher every day. The teachers to be observed were listed in random order each week. Over each four-day week eight teachers were observed. For procedural reliability, each activity of the teaching session was observed to determine whether there was compliance with the principles of Direct Instruction and Precision Teaching in the teaching instruction and the measurement of accuracy and fluency. If there was compliance with the principles a positive score was scored. If there was no compliance or partial compliance, a negative score was recorded. For each session, the number of positives was expressed as a percentage of the total number of activities. To determine recording reliability, the authors recorded the responses of the students at the same time as the teachers for each activity. Reliability for each activity was calculated by dividing the number of agreements by the number of agreements plus disagreements and the result was expressed as a percentage.

Procedural reliability for Group PT/DI and Group RP treatments was carried out by videoing 25% of the sessions. These sessions were coded at ten-second intervals by the first and third authors for compliance with the principles of that instructional procedure. If there was compliance, the interval received a positive score. If there was no compliance or only partial compliance, the interval received a negative score. Reliability for each activity was calculated by dividing the number of agreements by the number of agreements plus disagreements and the result was expressed as a percentage.

Recording reliability for Group PT/DI was carried out by simultaneous recording of a randomly selected child's responses by their partner and the first author during 25% of the sessions. Up to three students were observed each session. Reliability for each activity was calculated by dividing the number of agreements by the number of agreements plus disagreements and the result was expressed as a percentage.

RESULTS

Figure 1 shows that the average percentile ranking at the post-test increased by the same amount for all groups, regardless of the method by which they were taught (see appendix).

At follow-up the following year, the Individual PT/DI group increased their average percentile ranking, in contrast with the group RP subjects whose average percentile ranking had decreased. The follow-up check for group3, group teaching using PT and DI, will take place next year at the same time as the second follow-up check for groups 1 and 2.

The changes in percentile ranking of individual subjects are shown in Figure 2a, 2b, and 2c (see appendix). All subjects in the PT/DI groups obtained a higher ranking after teaching. Nine of the ten subjects in the RP group obtained a higher ranking, and one subject reduced his ranking by five places.

At follow-up, the situation showed greater variability. More subjects in the Individual PT/DI group than in the RP group continued to increase their ranking. Five of the 10 subjects in the Individual PT/DI group had increased their ranking from that achieved at the post-test, but a further three still had a ranking higher than that achieved in the pretest. In the RP group, three of the 10 subjects had increased their ranking from that achieved at the post-test, but five subjects still had a ranking higher than at the pretest.

The differences between pretest rankings and post-test rankings are summarised for the three groups in Table 1. The mean increase in percentile ranking was highest for the Individual PT/DI subjects and lowest for the Group PT/DI subjects. However, the range of increases of these two groups showed that all subjects had increased their ranking, while the range for the Group RP showed that some subjects had reduced their ranking. The PT/DI groups had higher top and lower rankings than the RP group. The size of the range was the similar for all groups.

Table 1: Mean changes in percentile ranking for each group between pretest and post-test.

Group	**Mean increase**	**Range High-Low +1**
Individual PT/DI	38.8	61 - 18 (+1) = 44
Group RP	15.5	40 - -5 (+1) = 46
Group PT/DI	9.6	43 - 2 (+1) = 42

The differences between post-test rankings and follow-up rankings for the Individual PT/DI and Group RP are summarised in Table 2. The Individual PT/DI group reduced their percentile rankings more than the RP group.

Table 2: Mean changes in percentile ranking for Individual PT/DI and Group RP between post-test and follow-up.

Group	**Mean PR change**	**Range High-Low +1**
Individual PT/DI	-21.8	-2 - -44 (+1) = -42
Group RP	-3.8	-9 - -22 (+1) = -13

The differences between pretest and follow-up rankings for the Individual PT/DI and Group RP are summarised in Table 3. There was a greater reduction in the mean percentile ranking for the Individual PT/DI group.

Table 3: Mean changes in percentile ranking for Individual PT/DI and Group RP between pretest and follow-up.

Group	Mean PR change	Range High-Low +1
Individual PT/DI	14.4	48 - -5 (+1) = 53
Group RP	11.7	41 - -3 (+1) = 44

DISCUSSION

The importance of addressing low mathematical performance with effective teaching methods is clearly demonstrated in this study. Mathematical performance needs to be maintained over time and to provide a basis from which students can continue to improve their skills without the need for continued remediation. It would appear that one of the following two factors is critical to these aspects of performance: the instructional method of Precision Teaching and Direct Instruction, or the one-to-one teaching situation. Until the follow-up results of the Group Precision Teaching and Direct Instruction subjects are received, the relative influence of these factors cannot be identified.

In Precision Teaching, the performance of skills at a high rate is taught. This level of performance results in automatic skill performance. It is possible that the level of automaticity in the component skills that the students in the Individual Precision Teaching and Direct Instruction group reached, enabled them to transfer these skills to new situations. This may have allowed their ranking relative to other students in the class to continue to increase after remedial teaching had finished.

In Direct Instruction, the component skills are identified and checked for successful performance before teaching occurs. If component skill level is not automatic, the new skill is not taught immediately, the component skills are taught first. This level of identification and assessment does not occur in Recommended Practice. Contributing skills are identified, but there is not the same level of systematic component skill analysis and teaching. It is possible that the number and nature of the component skills which were identified and taught, enabled the students in this instructional method to perform new skills which had some of the same component skills.

The influence of the one-to-one teaching situation may have been critical in the continued improvement of half of the students in the Individual Precision Teaching and Direct Instruction group. In individual instruction settings, the teacher is able to use all of the teaching time to address the needs of a single child. There is no wait time while other students are interacting with the teacher, or the teacher is teaching skills the child can already perform. The influence of this factor alone, cannot be determined until the follow-up results for the Group Precision Teaching and Direct Instruction group are received.

The role and structure of revision is not directly addressed in this study, but it may well be an additional critical factor in the maintenance of skills. In Precision Teaching and Direct Instruction, revision is structured in terms of content and its position in the structure of the lesson. Revision is also part of Recommended Practice, but there is not the same structure. It may be that targeting taught skills for regular review once a high level of fluency is achieved, contributes significantly to a student maintaining a higher ranked position in mathematical performance relative to their peers.

A factor which may have affected the performance of individuals across the groups is the distinction between low achievers and under achievers. A group which may be classified as underachievers reached

their fluency CAPs in a shorter time, and showed an increase in their percentile ranking in the post test.

There were incidental reports from teachers during the Individual Precision Teaching and Direct Instruction treatment and the Group Precision Teaching and Direct Instruction. Examples of such comments were "I have seen a definite improvement in her abilitiy at basic facts.", "a sharper mental arithmetic", "a complete change in attitude towards their ability at maths", "more confident", and "What have you done to K? She is performing much better than I would ever have expected." There were no comments from teachers during the Recommended Practice treatment. This could have been because the children had not reached a critical level of speed in skill performance to make an immediate difference to their classroom performance.

The responses from the children during the Individual Precision Teaching and Direct Instruction treatment were; "Can we do this next term?" , "My mum is buying me a watch with a face on it because I can tell the time.", and "I never knew that." During the Group Precision Teaching and Direct Instruction, children's comments were "We're so fast at maths." "This is easy." "Telling the time was hard but not now." "I can read numbers." During the Recommended Practice treatment, children said "We enjoy maths more.", "Maths is easy.", and "So that is how it goes."

Attitude change was not measured directly, but inferred from child comments and work practices during the teaching sessions. With the precision Teaching and Direct Instruction groups, the change was not just in test results but their attitude towards maths and their ability to try things out. This may have been because success was instant and measurable for them. They marked their work and they recorded their results. However, there was also a change in attitude with the Recommended Practice group which reflected a greater comfort and familiarity with the skills.

Among the issues future studies need to address, are the factors which contribute to attitude changes and what the nature of the changes in attitude are. The specific mathematics skills which contribute most to changes in national test scores need to be identified. A further area requiring investigation which has been highlighted by this study, is the relative contribution of individual instruction compared to group instruction.

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APPENDIX

Figure 1: Average Percentile Rankings (All groups)

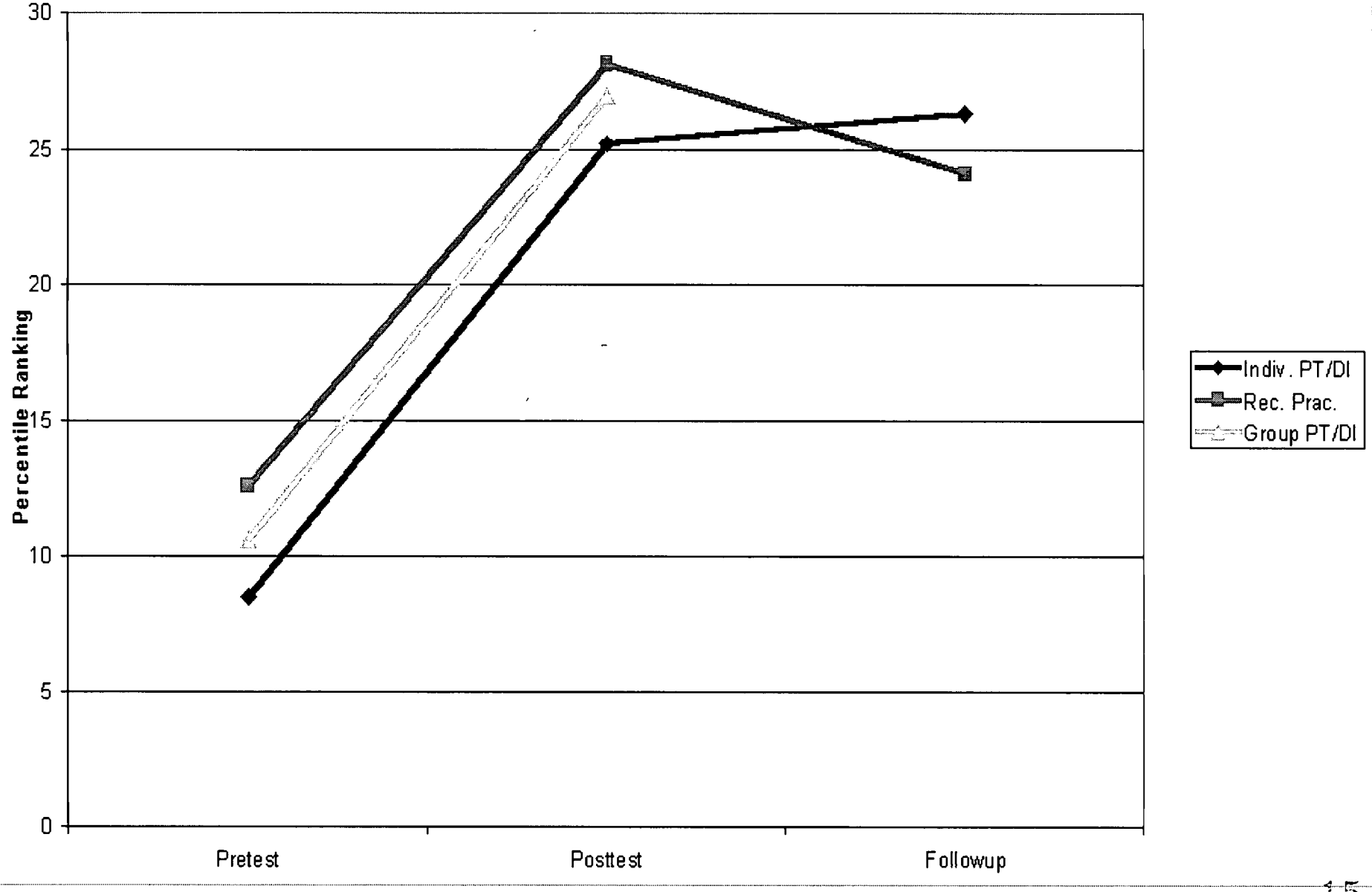


Figure 2a: Percentile Rankings for each Child in Individual PT/DI

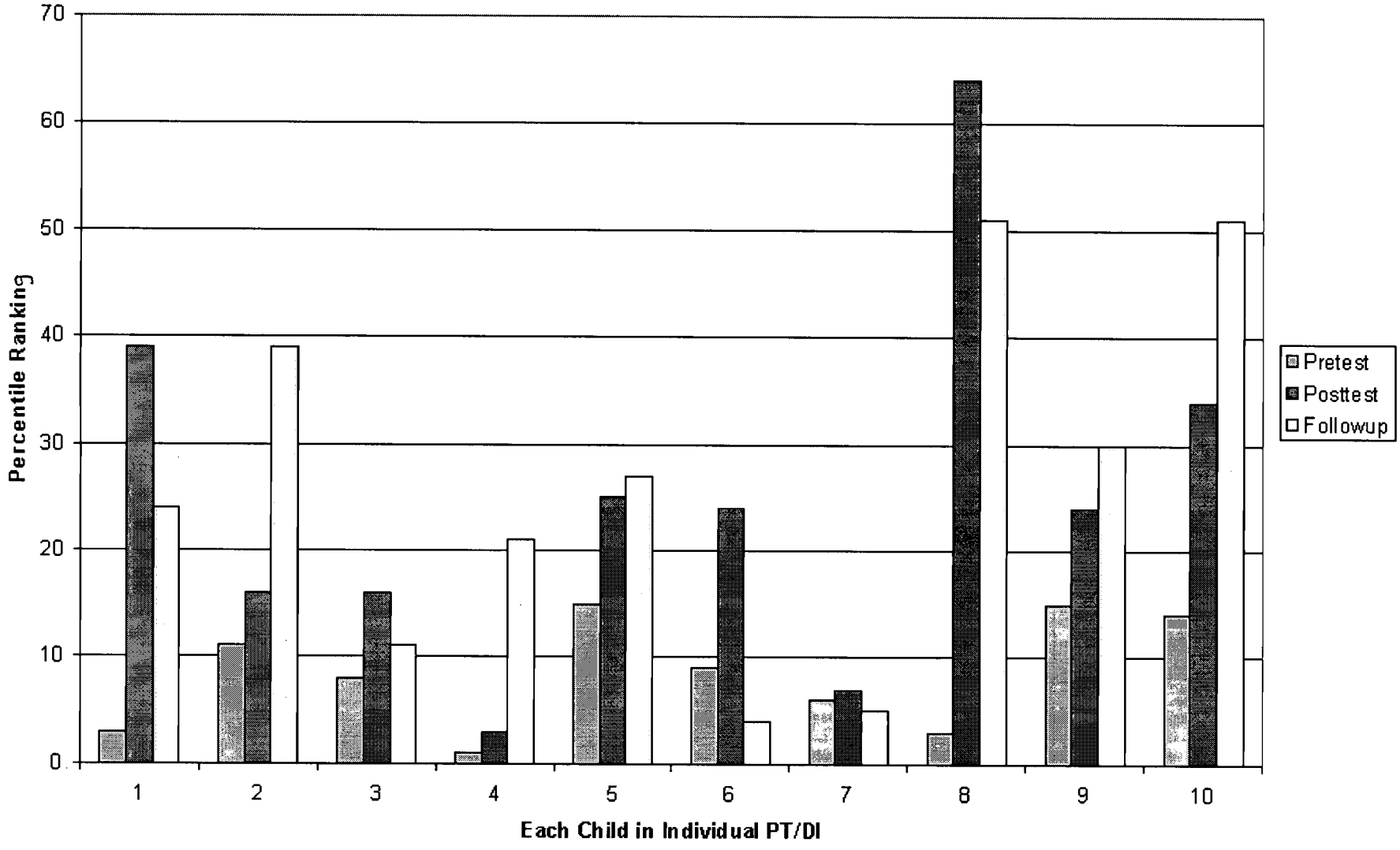


Figure 2b: Percentile Rankings for each Child in Group Rec Practice

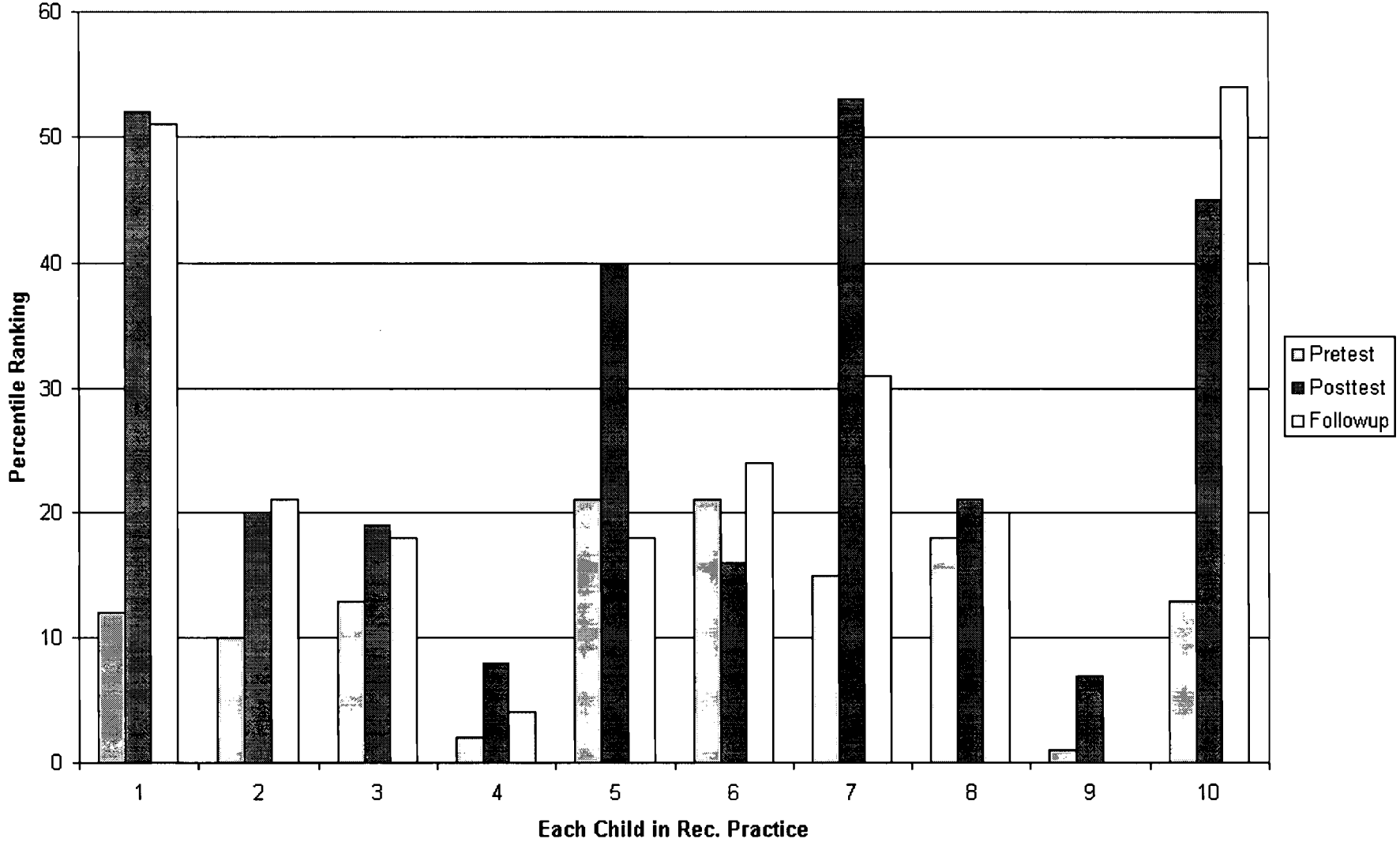
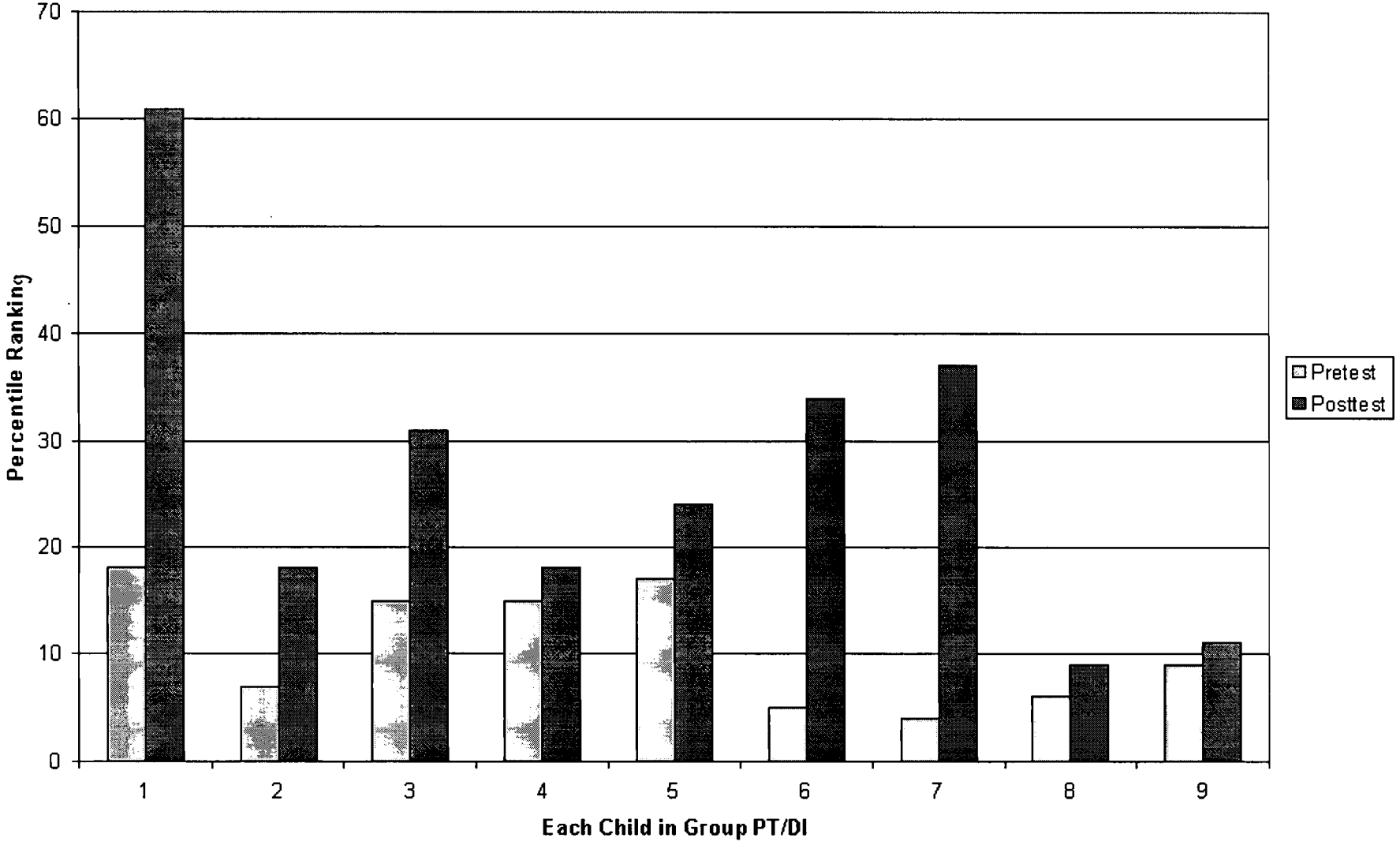


Figure 2c: Percentile Rankings for each Child in Group PT/DI



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