THE RELIABILITY AND VALIDITY OF THE ERHARDT DEVELOPMENTAL PREHENSION ASSESSMENT

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The reliability and validity of the EDPA
ABSTRACT

The Erhardt Developmental Prehension Assessment (EDPA) was designed as a measure of hand function for use with developmentally and physically disabled children. In this study the inter-observer reliability of the EDPA, and the concurrent validity of the EDPA with the fine motor scale of the Peabody Developmental Motor Scales (PDMS) were evaluated. The EDPA was initially revised by standardizing the procedures for administering the test and developing an objective scoring system. Thirty developmentally disabled children ranging in age from 3 to 18 months were tested in this study.

The results indicate that the EDPA has high levels of inter-observer reliability, and that it has concurrent validity with the PDMS in this population. Further test revisions are necessary, however, to improve the EDPA's discriminative power. Normative data needs to be gathered on a large, cross-sectional sample of children so that future measures of impaired hand function will be based on a good understanding of the sequence of normal development.
Le test Erhardt de l'évaluation de la préhension (EDPA) a été mis au point pour apprécier l'usage de la main chez les enfants handicapés physiques et les enfants présentant des troubles du développement mental. Cette étude a porté sur la fiabilité du test EDPA d'un observateur à un autre et sur la validité du test per rapport à la notation fine des échelles de motricité Peabody (PDMS). L'EDPA fut révisé tout d'abord par la standardisation des méthodes de conduite du test et par la mise au point d'un système d'évaluation objectif. Trente enfants retardés mentaux, âgés de 3 à 18 mois, ont fait l'objet de ce test.

Le test EDPA donne de très bons résultats quant à l'interprétation d'un observateur à un autre. Dans la population étudiée, le test indique aussi une validité des résultats comparable avec ceux du PDMS. Cependant, d'autres révisions sont encore nécessaires pour améliorer le pouvoir discriminant du test EDPA. Il est nécessaire de réunir des données normatives sur un échantillon d'enfants, à la fois large et très représentatif, pour pouvoir à l'avenir baser la mesure des troubles de motricité de la main sur une bonne compréhension de la séquence d'un développement normal.
I would like to express my gratitude to many people who have contributed to this project.

To Rhoda Erhardt for designing the original assessment that provided the basis of this research.

To the families and staff of the Peel Infant Development Program and the Halton Parent-Infant Program, in particular, Lorna Montgomery and Mary Lane for their interest, enthusiasm and participation.

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To Mary Law for taking on a "foreign" student and providing ideas, resources, time, criticism, and above all encouragement whenever it was needed.

And finally, to my parents and my friends, in particular, Kathy Berg and MaryAnn McColl who supported me throughout this lengthy process.
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INTRODUCTION

The development of human infants is influenced by the combined effects of their genetic endowment and environment. In addition, this process depends on the interaction between physical maturation, and the development of cognitive, motor and social abilities. These physical and behavioural aspects of the child develop simultaneously and there is a great deal of interdependence among them. Formal evaluations of this developmental process, such as the Bayley Scales of Infant Development (Bayley, 1969), separate behaviours into broad categories for ease of testing, but these divisions are artificial given the interdependence between different areas of development. Since motor behaviour is directly observable, motor development is one of the easiest skill areas to assess in the young child. However, such behaviour must also be considered a reflection of less obvious developmental processes, such as spatial reasoning and problem-solving abilities.

In the first 6 or 7 years of life, play serves as the vehicle through which the child explores the environment and learns many of the basic skills required for independence in adulthood. Many of these play experiences, particularly in the early period of development, involve touch, movement and the manipulation of objects. To achieve optimal learning and to develop the skills and competencies essential to their
well-being as adults the child requires strength, normal sensation and fine motor dexterity.

A child with abnormal motor development, will have difficulties in daily functioning as well as in play activities, particularly if hand function is affected. An infant with cerebral palsy, for example, may have limited arm movement due to increased muscle tone with poor postural stability, and be unable to bring the hands to midline, or to the mouth, interfering with exploratory play and feeding.

It is estimated that out of every 1000 live-births in the province of Ontario three will have developmental problems (Ontario Ministry of Community and Social Services, 1982). In Ontario, there are more than 40 Infant Therapy Programs serving approximately 1600 children and their families. Of the children referred to these Infant Therapy Programs, 67% have been identified as having delays in their development. On initial assessment, 29% of the children accepted into the programs show specific motor problems, including delayed fine motor development. Occupational therapists and other program staff provide treatment, and consult with parents with the aim of alleviating these disabilities. Before remediation, however, therapists must first be able to identify accurately those children with motor problems, and particularly those with hand dysfunctions.

At present, there are few assessments available for testing the young child. This literature review will
describe the assessments currently available to measure hand function in children, review the normal development of hand function, and will then focus specifically on the Erhardt Developmental Prehension Assessment.

The Development of Hand Function

Much of our current knowledge about the development of hand function is based on the early work of developmental theorists such as Hal'erson (1931, 1937) and Gesell (Gesell & Halverson, 1936). These authors used cinematic recordings of infants from 16-52 weeks of age to analyze the sequence of fine motor skill development. They recorded three principal categories of visuomotor behaviour: visually directed gaze (regard), hand approach (reach), and grasp. Ten stages of grasp were identified during this period of development, from (1) no contact with the object, through (6) palmar grasp, to (10) superior forefinger grasp. Each type of grasp represents a further refinement and differentiation of finger and thumb movement.

Based on this classic work (Halverson, 1931), sequences of fine motor skill acquisition have been included in many developmental checklists and assessments as part of larger, more general batteries (e.g., Bayley Scales of Infant Development, 1969, Griffiths Mental Development Scale, 1954). For the most part, the developmental age levels and
progressions reported by Halverson (1931) are still used today.

In addition to studying the overall pattern of development of hand function, researchers, particularly in the field of psychology, have looked at specific aspects of hand function during infant development. For example, von Hofsten (1979) and DiFranco, Muir, and Dodwell (1978) studied eye-hand coordination and the development of visually directed reaching in infants. They demonstrated that reaching occurred in response to a visual stimulus in infants as young as 15 weeks of age, and suggested that eye fixation and reaching in the newborn serve as part of the infant's information gathering system (von Hofsten, 1982).

Bower (1977) has identified two phases of reaching, one that occurs prior to 4 weeks of age, that is visually initiated and involves gross arm movements, and a second phase occurring after 4 months of age that is visually controlled, differentiated, and goal directed. Reaching often disappears between these two phases. Vision appears to act initially as a preparatory system, providing information that assists in the formation of grasp, and then the tactile system predominates once the object is in the hand (Bower, Broughton & Moore, 1970). Visually directed prehension usually develops by 16-20 weeks of age, although the time of appearance is related to the gestational age and weight of the infant at birth (Paine, Pasquali & Speqiorin, 1983).
Other authors have studied the relationship between reflexive behaviour in the newborn infant and prehensile skills in the first year of life. Coryell and Henderson (1979) found that the asymmetrical tonic neck reflex (ATNR) plays a role in the development of eye-hand coordination. They suggest that the ATNR is at its strongest at the time that infants start to be aware of their hands, and that the reflex helps to bring the hand into the visual field, and so facilitates viewing of the hand. Twitchell (1965) and Pollack (1960) have focused their studies of reflexive behaviour on the grasp response in the neonate, which is the reflex response of the hand to a stimulus placed in the palm. They found that this reflex appears between 1 and 3 months of age in normal infants and consists of a catching and holding phase. More recent authors have refuted these results suggesting that the form of the grasp reflex can vary over repeated trials and depends on many situational factors, such as posture, head position, and behavioural state (Touwen, 1978).

Ammon and Etzel (1977) proposed an organizational model of the sensorimotor development of reach and prehension during the first twelve months of life, that was again based on the work of early developmental theorists (Gesell & Amatruda, 1949; Halverson, 1931; Twitchell, 1965), and on existing infant scales. Five components of hand skills were included in their model: grasp and avoidance reflexes, visual responses, reaching, grasping and
prehension, and emerging manipulative behaviours. Within each component, the progressive refinement of skills was described from birth to twelve months of age. The authors suggest that this organizational model of prehensile development could be used in planning interventions for developmentally disabled infants.

Hohlstein (1982) studied the longitudinal development of prehension in normal infants aged between 4 and 12 months in order to examine whether the developmental sequence described by Halverson in 1931 was still valid 50 years later. She suggested that hand function becomes increasingly specialized and precise during the first year of life, from the use of the whole hand for grasping to use of the distal portion of the thumb and fingers. The children in her study showed similar sequences of development to the children in Halverson's study although they achieved grasp components at an earlier age (usually 1 - 2 months sooner). She also found a high degree of variability in the infants' responses, and suggested that current assessment methods, which typically involve rating a single evoked response, were of questionable value.

The Assessment of Hand Function

Kirshner and Guyatt (1985) propose that measures of health status can be divided into three broad categories according to their purpose. Measures may be either
discriminative, evaluative, or predictive, and any assessment tool could serve functions within each of these three categories. With the recent emphasis on early intervention with children who have developmental problems (Schaefer, Hatcher & Barglow, 1980; Simeonsson, Cooper & Scheiner, 1982), a discriminative measure of hand function would be useful in distinguishing between those children experiencing sensorimotor problems and those developing normally, in order to facilitate early detection and intervention.

Occupational therapists could use such a tool in an evaluative capacity to monitor change in hand function over time or to document progress over the course of treatment. In addition, an assessment could function as an evaluative tool and be used as an outcome measure in studies of treatment effectiveness, where therapy is aimed at improving fine motor control.

Results from studies in which the development of premature infants has been examined in an effort to determine predictors of normal neuromotor outcome have been mixed (Dubowitz et al., 1984; Hadders-Algra, Touwen & Huisjes, 1986; Harris & Brady, 1986; Ross, Lipper & Auld, 1986; Skouteli, Dubowitz, Levene & Miller, 1985.) Assessments of muscle tone, reflexes and gross motor behaviour (e.g. head control in a prone position) have not shown predictive value with low birthweight infants (Deitz, Crowe & Harris, 1987). It may be that these behaviours are
too gross and that subtle problems in motor development are
difficult to recognize at such a young age. Given the
precise nature of prehension, it may be possible to detect
these subtle, but important, differences in motor
development by evaluating hand function in the very young
child. An assessment of fine motor function could have
predictive value if these early motor problems were shown to
be correlated with later disabilities.

For the purpose of this study, emphasis will be placed
on the development of a discriminative measure, that is, a
measure that can distinguish between individuals or groups
(Kirshner & Guyatt, 1985). Such a measure should include all
the important components of the domain under study, and
should be applicable to all those within the target
population. A measuring instrument is usually composed of a
number of items which assess different aspects of
performance. The items should show internal consistency,
that is, each item should contribute to the measurement of a
single construct. The test should be standardized by stating
the qualifications required of the tester, the nature of the
test environment, the ordering of the items, and the
procedures for administration. It should be reliable when
used by different observers and over repeated
administrations. Most importantly, the test must be
measuring what it is intended to measure. This property,
validity, must be examined on an ongoing basis. Test
developers must also consider the acceptability of the test
to the target-user group. Cost, ease of administration, format, respondent burden and the time required to administer the test must all be taken into account (Benson & Clark, 1982, Law, 1987).

Most assessments of hand function have been developed for use with adults to measure muscle strength, range of joint motion, sensory status and the functional performance of the hands (Evans & Lawton, 1984; Jebsen, Taylor, Trotter & Howard, 1969; Kellor, Frost, Silberberg, Iverson & Cummings, 1971; Mathiowetz, Volland, Kashman & Weber, 1985; Skerik, Weiss & Platt, 1971). A survey conducted by Smith and Benge (1985) reported that even among evaluations of physical capacities, such as pinch strength, there is a lack of standardized protocols and inconsistent use of terminology. Some of these tests of hand function have been adapted for use with children, and normative data have been collected on children from 5 to 19 years of age. The focus of these tests has been on measures of strength (Ager, Olivett & Johnson, 1984), and coordination (Gardner & Broman, 1979; Mathiowetz, Federman & Weimer, 1985), as well as on functional activities such as writing and eating (Taylor, Sand & Jebsen, 1973). These tests have not assessed the development of prehension in the younger child.

Sand and his colleagues (Sand, Taylor, Hill, Kosky, & Rawlings, 1974; Sand, Taylor, & Sakuma, 1973) have applied the test modified by Taylor (1973) to different clinical populations, including children with myelomeningocele and
mental handicaps. In this test children are timed as they complete seven manual activities: writing, turning over cards, picking up small objects, simulated feeding, stacking checkers, and picking up large, light and heavy objects. Results showed that this test was reliable, and could discriminate neurologically and mentally handicapped children from normal school-aged children on the basis of their speed of performance.

There have been few attempts to measure hand function in the infant or young child. Lundberg (1979a) described an assessment procedure in which arm and hand function was studied in children aged between one and three years. Her evaluation measures hand preference, posture, and the type of grasp used during a drawing task. The author has used the test with a cohort of children aged 15 and 18 months (Lundberg, 1979b), and showed more refined prehensile patterns in the 18 month-old group as compared to the 15 month-old group. This assessment has not been standardized and norms are not available for other age groups.

Another test used to assess motor function in children, the Peabody Developmental Motor Scales (PDMS), includes items that measure fine motor skills (Folio & Fewell, 1983). This scale was designed to identify children whose motor skills are delayed or aberrant relative to the normative group, and to assist in planning for remedial programs. The fine motor items have been grouped into four categories: reflexes, eye-hand coordination, hand use, and manual
dexterity, and the test scale was standardized on children from birth to seven years of age. Items are grouped in 2-month increments from birth to 12 months of age, in 5-month increments from 1 to 5 years of age, and in 11-month increments from 5 to 7 years of age. There are 6-8 test items in each age grouping. The position of the child, the test equipment and the verbal instructions are described for each item. Scoring is on a three-point scale with specific criteria given to judge the child's performance. Children are given credit for partial completion of test items, but there are few descriptors of the quality of the performance expected.

The PDMS have been standardized in the United States using a stratified sample (n=617), and norms from birth to seven years of age have been published. The test-retest and inter-observer reliability are very high, and the PDMS have demonstrated construct validity. Scores on the PDMS are positively correlated with those on the mental scale of the Bayley Scales of Infant Development (Palisano, 1986a), and the PDMS are widely used and accepted by occupational therapists in pediatric practice.

The authors suggest that the PDMS can be used with handicapped children, although their scores cannot be compared to the norms given. They suggest using scaled scores to monitor changes in the handicapped child's performance, however, the lack of qualitative descriptors may limit the use of the PDMS with disabled children. Test
items in the PDMS may not be responsive to the changes expected in the disabled child's hand function.

The Erhardt Developmental Prehension Assessment

Working from the earlier sequential models of the development of prehension (Gesell & Halverson, 1936), Erhardt, Beatty, and Hertsgaard (1981) constructed a developmental prehension assessment for use with handicapped children. The authors saw the need for an assessment tool that was objective, measured both the quality and quantity of motor performance, included both reflexive and volitional motor behaviours, was sensitive to small changes in performance, and was designed specifically for infants.

Item selection was based on a review of existing motor-development scales. Items were included if there was at least 50% agreement among nine selected sources on the time of development of the particular behaviour. Scoring was modelled after the Gesell Developmental Schedules (Gesell & Amatruda, 1949), where patterns of movement were classified on a four-point scale as (1) well established, (2) not achieved, (3) not fully integrated, or (4) temporary, to be replaced by more mature patterns. The test was designed to be used with disabled and developmentally delayed children, but includes age levels (in one-month increments) based on the normal progression of development from birth to 15
months. The EDPA was designed to provide information to assist in treatment planning.

Following its development, the Erhardt Developmental Prehension Assessment (EDPA) was pretested by occupational therapists and was subsequently revised. Erhardt (1982) conducted one study on the inter-rater reliability of the instrument in which 16 raters were trained in the scoring of the test and then divided into two groups. Each group rated videotapes of two children being assessed by the author and inter-rater agreement was calculated using intraclass correlation coefficients. The coefficients ranged from 0.42 to 0.85 showing a wide discrepancy from unacceptable to high levels of agreement. Revisions were subsequently made based on a test-item analysis. Items with low correlations were examined for imprecise definitions, an excessive number of components or problems of subjective judgement, and were subsequently rewritten. The final revision was published in 1982 as the Erhardt Developmental Prehension Assessment.

The EDPA is now generally available to therapists. In its current form, however, it is lacking in many of the psychometric properties required of a standardized, objective measure of hand function. The test instructions are not clearly presented, and the testing environment and order of item administration are not specified. Many of the test items require interpretation on the part of the examiner in order to score them, which limits their objectivity and reliability. There is no method of
aggregating the scores once the test has been administered, and hence use of the test for decision-making purposes is limited. Developmental norms are based on previous studies, however, Erhardt is currently in the process of gathering normative data. Other forms of reliability, including test-retest and internal consistency, have not been assessed, and many questions regarding the validity of the EDPA remain unanswered.

Occupational therapists in several clinical settings were contacted regarding their use of the EDPA, and they reported that they use the assessment as a guideline for treatment planning and for monitoring progress, but not as a measurement tool. They find the breakdown of the test items into specific components useful and feel that it adds valuable information about the quality of hand movements, but are not able to use the scoring system as it is currently defined.

Summary

Well-developed hand function is required for achieving meaningful occupation in adulthood, and also serves an important role in the learning process in childhood. Despite its importance, relatively little emphasis has been placed on understanding either the sequence of normal prehensile development, or the deviations from normal development that may occur.
Hand-function measures designed for adult, orthopaedic populations have been adapted for use with school-aged children, but these tests usually do not assess more subtle, qualitative aspects of performance which may be very important when assessing a child with neurological or developmental problems. Some research has been done with infants in which the development of visually directed reaching has been studied, but, for the most part, normative data gathered in the 1930s is still being used today in developmental scales.

Erhardt has addressed the need for a measure of prehensile skill development in the infant, and designed the EDPA as an assessment tool. In its current form, however, it is difficult to administer and score this test, and many issues concerning the reliability and validity of this instrument remain unresolved. The EDPA does address an area of need for occupational therapists working in pediatrics, but requires further investigation and revision in order to improve its clinical applicability.

Present Investigation

In the present study, further refinement of the EDPA was undertaken; however, this work represents only a part of the process of test development. The study was designed to develop the EDPA as a discriminative measure, with particular application to the early detection of fine motor
problems. This study does not test the discriminative ability of the EDPA, but rather focuses on standardization of the test, and evaluating its reliability and validity. Further studies will be required to continue the process of validating the EDPA as a discriminative tool.

The specific objectives of this study were:

1. To standardize the administration and develop a scoring procedure for the EDPA.

2. To evaluate the inter-observer reliability of the revised EDPA using a sample of developmentally disabled infants.

3. To test the concurrent validity of the revised EDPA by comparing the results on this test with those on the fine motor scale of the Peabody Developmental Motor Scales using a sample of developmentally disabled infants.

The first step was to revise the administration and scoring of the EDPA. Developmentally and/or physically disabled infants were then tested on one occasion using this revised version of the Erhardt Developmental Prehension Assessment and the fine motor scale of the Peabody Developmental Motor Scales. A second observer scored the EDPA and the results from the two scorers were analyzed to determine inter-observer reliability. Erhardt, in her development of the EDPA, addressed the issue of content validity by reviewing the literature and consulting with
clinicians. The validity of a measure can also be evaluated in terms of its concurrent validity. This type of validity is empirically measured by determining the extent to which a given measure agrees with another estimate of the same criterion, when both measures are administered in the same test session (Maslany & Weston, 1977). Selecting the criterion measure is often difficult particularly when there is no recognized gold standard, which is certainly the case in assessing the development of hand function. For the purposes of this study, the fine motor scale of the Peabody Developmental Motor Scales (p. 10) was used as the criterion measure (Folio & Fewell, 1983). Test results on the EDPA and the PDMS were analyzed to determine their concurrent validity.
METHODS

Subjects

The subjects in this study were selected from children currently served by the Peel Infant Development Program in Mississauga, Ontario and the Halton Parent-Infant Program in Burlington, Ontario. These programs provide service to children from birth to thirty months of age who have been identified as being at risk for developmental problems. The population served is divided into three categories: established risk, (i.e., presence of a medical diagnosis); biological risk, (i.e., traumatic birth history, insult to the central nervous system); and/or psychosocial risk, (i.e., environmental deprivation, family problems) (Ontario Ministry of Community and Social Services, 1987). Public health nurses and family practitioners are the primary referral sources. The programs use a mediator model of intervention, where the focus is on parent education and training. Ninety percent of the contact is on an individual basis and takes place in the child's home. The mean frequency of visits by program staff is 3 visits per month. Some of the parents and children are also involved in monthly group programs.
Children from these two programs fulfilling the following criteria were eligible for the study:

- chronological age between 3 and 18 months (adjusted age scores were used for those children born prior to 36 weeks gestation).
- identified by a physician as delayed in development
- currently receiving services from an infant development program

Children with the following disabilities, as described in their medical records, were excluded from the study:

- visual impairments
- congenital anomalies of the upper extremities (e.g., amputations, upper limb foreshortening)
- severe neurological deficits (e.g., cerebral palsy-spastic quadriplegia).

Parents of children fulfilling the eligibility criteria were approached regarding the study by infancy consultants or therapists working in the infant programs. Written consent (Appendix 1) was obtained from each family and this gave the investigator permission to make direct contact with the family.

A second consent form was signed during the visit to the child's home. This consent was an agreement that covered
participation in the study and allowed the results to be made available to the referring program (Appendix 2).

Thirty children were assessed in their homes between May and October, 1987. The sample-size estimate (n=30) was calculated using Fisher's z transformation on the formula for a 95% confidence interval around an expected validity correlation coefficient between the EDPA and the PDMS of 0.70 (Kleinbaum & Kupper, 1978). This correlation level was selected on the basis of the similarity of the items comprising these two tests.

Twelve children were from the Halton Parent-Infant Program and 18 were from the Peel Infant Development Program. The children (15 male, 15 female) ranged in chronological age from 4 to 22 months, with a mean age of 12 months (see Table 1). Corrected ages (i. e., adjusted for prematurity) ranged from 1 week to 19 months of age, with a mean age of 11 months. Five of the subjects were born prior to 36 weeks gestational age. Birthweights ranged from 760 grams to 4090 grams with a mean of 2864 grams.
Table 1

Age and Birthweight Characteristics of the Sample

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chronological age (months)</td>
<td>12</td>
<td>4.8</td>
<td>4-22</td>
</tr>
<tr>
<td>Adjusted age (months)</td>
<td>11</td>
<td>4.9</td>
<td>0-19</td>
</tr>
<tr>
<td>Gestational age (weeks)</td>
<td>37</td>
<td>4.4</td>
<td>26-42</td>
</tr>
<tr>
<td>Birthweight (grams)</td>
<td>2864</td>
<td>911</td>
<td>760-4090</td>
</tr>
</tbody>
</table>

The developmental problems seen in this sample of children resulted from a number of medical conditions as shown in Table 2. The most frequent etiology, accounting for 60% of the sample, was Down's syndrome.

Table 2

Medical Diagnoses of the Children

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Down's syndrome</td>
<td>18</td>
<td>60.0</td>
</tr>
<tr>
<td>Prematurity</td>
<td>5</td>
<td>16.8</td>
</tr>
<tr>
<td>Developmental delay</td>
<td>4</td>
<td>13.3</td>
</tr>
<tr>
<td>Cerebral palsy</td>
<td>1</td>
<td>3.3</td>
</tr>
<tr>
<td>Hydrocephalus</td>
<td>1</td>
<td>3.3</td>
</tr>
<tr>
<td>Achondroplasia</td>
<td>1</td>
<td>3.3</td>
</tr>
</tbody>
</table>
Many of the children had experienced medical complications since birth. Seventy-seven percent (n=23) of the subjects had experienced one or more complications, and seven percent (n=2) had experienced three or more. Heart defects, most commonly ventricular-septal defects, and respiratory problems such as recurrent respiratory distress were the most frequently occurring complications (see Table 3). Sixty-seven percent (n=20) of the children had been hospitalized at least once since birth, with the duration of the hospital stay ranging from a few days to nine months.

Table 3

Medical Complications

<table>
<thead>
<tr>
<th>Type of complication</th>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart defect</td>
<td>12</td>
<td>52.2**</td>
</tr>
<tr>
<td>Respiratory problem</td>
<td>12</td>
<td>52.2</td>
</tr>
<tr>
<td>Gastro-intestinal problem</td>
<td>5</td>
<td>21.7</td>
</tr>
<tr>
<td>Hearing impairment</td>
<td>1</td>
<td>4.4</td>
</tr>
</tbody>
</table>

* Percentages calculated from group with one or more complications (n=23).

** Percentages are not cumulative, as some subjects had more than one complication.
All of the children had been identified as being at-risk for developmental problems very early, with 20% of the sample (n=6) being identified at birth (see Table 4). The mean age of the children at the time of referral to the programs was 4.5 months. At the time that the assessments were conducted for this study, the mean length of time that the children had been involved in the program was 8 months, with a range of 1 to 18 months.

Table 4

Age at Referral to Infant Program.

<table>
<thead>
<tr>
<th>No.</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth</td>
<td>6</td>
</tr>
<tr>
<td>1-4 months</td>
<td>15</td>
</tr>
<tr>
<td>5-11 months</td>
<td>5</td>
</tr>
<tr>
<td>12-18 months</td>
<td>4</td>
</tr>
</tbody>
</table>

As part of the data collection process for this study, parents were asked to recall the age at which the following developmental milestones were acquired: rolling from prone to supine, sitting independently, creeping, and walking unaided. In Table 5, the mean age of achievement of these milestones in the sample is compared to published norms.
based on a survey of nine developmental tests (Touwen, 1974).

Table 5

Achievement of Developmental Milestones

<table>
<thead>
<tr>
<th>Milestone</th>
<th>Normal age of achievement (months)</th>
<th>Mean Age achieved (months)</th>
<th>No. of subjects who achieved milestones as a proportion of those expected to achieve the milestone at that age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rolling</td>
<td>5</td>
<td>6.5</td>
<td>26/28</td>
</tr>
<tr>
<td>Sitting</td>
<td>8</td>
<td>9.5</td>
<td>19/23</td>
</tr>
<tr>
<td>Creeping</td>
<td>10</td>
<td>12.5</td>
<td>13/21</td>
</tr>
<tr>
<td>Walking</td>
<td>13</td>
<td>19.0</td>
<td>1/14</td>
</tr>
</tbody>
</table>

Test Standardization

Prior to collecting data on the test's reliability and validity, the administration and scoring criteria of the EDPA were revised. The following steps were taken:

1. The EDPA is divided into two main categories: positional-reflexive patterns, and cognitively directed movements, with several skill areas in each category (see Appendix 3). In the revision, the test was divided into six categories based on the type of skill being measured. These categories are
reflexes, posture, reach, grasp, manipulation, and release (see Appendix 4).

2. Test items were ordered in one-month increments from birth to 6 months, and in 2-month increments from 7-8 months to 11-12 months of age. These groupings reflect the rapid developmental changes occurring in the first 6 months of life. The EDPA also uses one-month intervals, but these are not consistently defined in the different categories; for example, the manipulation category has test items for natal, 1, 3, 4, 5, 6, 7, 8, 9, 10, 12, and 15 months, whereas the avoiding-response category has test items for fetal, natal, 1, 2, 3, 5, and 6 months of age.

3. The test was divided into quantitative and qualitative sections. Each test item has one quantitative component that is scored, and four qualitative components that describe the performance and provide the basis for the scoring.

Example: 1a. Position - supine  L  R

<table>
<thead>
<tr>
<th>PATTERN</th>
<th>COMPONENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>[ ] midline control</td>
<td>[ ] [ ] head in midline</td>
</tr>
<tr>
<td></td>
<td>[ ] [ ] shoulders depressed</td>
</tr>
<tr>
<td></td>
<td>[ ] [ ] arms reach to midline</td>
</tr>
<tr>
<td></td>
<td>[ ] [ ] hands open</td>
</tr>
</tbody>
</table>
4. Scoring is on a three-point scale based on the presence or absence of the components of each skill.
   - 0 = absent, no components observed
   - 1 = emerging skill, 1-3 components observed
   - 2 = present, all 4 components observed

Full credit is given to skills that are present at earlier developmental ages, but are not assessed. This differs from the EDPA scoring which uses four possible scores (p. 12).

5. Reflex items (asymmetrical tonic neck reflex, grasp reflex, instinctive grasp reactions, proprioceptive placing, protective reactions, and avoiding responses) are not included in the aggregate total, but are scored as absent or present according to specific response criteria. Reflex responses are difficult to elicit consistently and depend on the child's position, activity level, time of day, and the stimulus presented. The relation between reflexes and functional performance is also poorly understood. For these reasons the reflex items were not scored in the same manner as the other items and were not included in the aggregate total.

6. Score totals are summed for each skill category. As categories contain different numbers of items, a percent score is calculated for each category based on the expected score (from the developmental levels in the EDPA) and the
adjusted age (p. 18) of the child. In total, there are 67 items grouped as follows:

Posture - Supine - 7 items
   Prone - 8 items
Reach - Supine - 6 items
   Prone - 7 items
   Sitting - 6 items
Grasp - Dowel - 6 items
   Block - 6 items
   Pellet - 4 items
Manipulation - 8 items
Release - Block - 6 items
   Pellet - 3 items

This represents approximately half the number of items in the EDPA (131 items). The deletion of the reflex items from the main body of the test accounted for most of this reduction. Percentage scores for each of the five categories are summed and divided by five to yield a total percentage score. In this way implicit weighting of the categories is avoided.

7. A cover page of the test manual provides information about the testing environment, materials needed, and procedures for administration and scoring. In addition, each skill category has specific instructions concerning the administration of the items. The manipulation category has
directions for each item because the positions and test materials change within that category. Pictures from the EDPA illustrating the various skill levels are included for clarification.

8. Two score sheets are available for summarizing the item scores, aggregating the scores, and plotting the child's performance. A comments section allows the observer to record observations made during testing.

The revised format was pretested on five normal children ranging in age from 1 to 14 months. These test sessions were videotaped and subsequently used for training the second observer for the reliability study.

Testing Procedures

The children were seen in their homes at a time prearranged with the parent. Testing was usually done on the floor and/or in a high chair depending on the child's age and mobility. The study was again explained to the parent and he/she was free to ask questions during the visit. Background information regarding the child's birth history, diagnosis, family situation, hospitalizations and illnesses, developmental history, and involvement with health and community services was obtained from the parent.
Test sessions usually lasted from 45 to 60 minutes. The revised EDPA and the PDMS (see Appendix 5) have several test items in common, so were often scored simultaneously. Because there is no specific order of administration for either test, materials were presented to the children according to their interest, so as to elicit an optimal level of responding. Most of the children did cooperate with the investigator, however, on two occasions the parents had to present the test items to the child with the investigator giving directions.

For the first twenty assessments, a second observer was present and independently scored the EDPA. The observer, a senior occupational-therapy student, was trained over two sessions. In the first session, the investigator and student went through the test item by item to ensure that the descriptions of the pattern components were clear. The second session consisted of each observer independently scoring the videotapes of five normal children. The criterion level of 75% agreement (i.e., agreement on at least 50 out of the 67 test-item scores) was reached on the initial scoring of each tape. Items on which there was disagreement were subsequently discussed and the procedure clarified.

The results of this study and the interpretation of those results pertain only to this revised version of the EDPA.
RESULTS

All of the 30 subjects were tested using the EDPA. One subject refused to cooperate during administration of many of the test items on the PDMS, and so only 29 scores are available for this test. The scores on the EDPA ranged from 29% to 100% (a score of 100% represents normal development). On the PDMS scores ranged from 16% to 100%. Table 6 shows the group mean scores on each skill category of the EDPA, and the total test scores on the EDPA and PDMS. Mean scores for each category were graphed on each subject's summary score sheet.

Table 6

Test Results on the EDPA and PDMS

<table>
<thead>
<tr>
<th>Category</th>
<th>Mean (%)</th>
<th>SD (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posture</td>
<td>91.5</td>
<td>15.8</td>
</tr>
<tr>
<td>Reach</td>
<td>89.1</td>
<td>18.3</td>
</tr>
<tr>
<td>Grasp</td>
<td>77.4</td>
<td>18.0</td>
</tr>
<tr>
<td>Manipulation</td>
<td>74.3</td>
<td>18.7</td>
</tr>
<tr>
<td>Release</td>
<td>55.9</td>
<td>25.2</td>
</tr>
<tr>
<td>Total EDPA</td>
<td>77.6</td>
<td>16.2</td>
</tr>
<tr>
<td>Total PDMS</td>
<td>62.7</td>
<td>22.8</td>
</tr>
</tbody>
</table>
Total test scores on the EDPA were calculated by age and diagnostic groups. The mean score of children with Down's syndrome (n=18) was 76.8 (SD=13.0), and for children with other diagnoses was 79.0 (SD=20.8). When the subjects were grouped by age, those 12 months of age or younger had a mean score of 78.5 (SD=20.8), whereas the children older than 12 months had a mean score of 76.5 (SD=16.9). There were no significant differences (t test, independent groups) on the EDPA scores between the diagnostic groups, or between the age groups.

Reliability

Two estimates of reliability were calculated. First, the internal consistency of the whole test and of each category was calculated using Cronbach's alpha and second, the inter-observer reliability. Coefficient alpha is derived from the number of items in the test and the average inter-item correlation (Carmines & Zeller, 1979), and is calculated from an extension of the formula used for determining split-half reliability coefficients. It represents the average of all the possible split-half coefficients for a given test, and provides a lower-bound estimate of reliability (Cronbach, 1951).

Percentage scores for each skill area of the EDPA were calculated for all subjects based on the observed score and the expected score for the child's age. This resulted in
scores for the following eleven skill areas: posture-supine, posture-prone, reach-supine, reach-prone, reach-sitting, grasp-block, grasp-dowel, grasp-pellet, manipulation, release-block, and release-pellet. These data were analyzed using the reliability program of SPSS-X (1986), which calculates the internal consistency of the measure (Cronbach's alpha), that is, how much each skill area contributes to the total test score. These results are shown in Table 7. The alpha coefficient for the total test was 0.89 indicating that there is a high level of internal consistency.

The correlations between each skill area and the total score were also calculated. Scores in the skill areas of grasp-dowel, grasp-block and manipulation were highly correlated with the score on the total test, whereas scores on reach-sitting, and particularly on release-pellet have much lower correlations with the total test score. A further analysis was done in which the alpha coefficient was re-calculated as the score in each skill area was removed in turn from the analysis, and then replaced. Again, the coefficient remains high and shows little variation.
The second measure of reliability calculated was interobserver reliability. Scores from the principal investigator and a second observer were analyzed using the intraclass correlation coefficient that takes into account both the agreement between observers, and the differences between the overall means (Kramer & Feinstein, 1981). Coefficients exceeding 0.75 were considered acceptable. The intraclass correlation coefficient was calculated for each skill area and for the total test score, and the alpha if item deleted was also computed for each skill area.

### Table 7

**Reliability Analysis - Internal Consistency of EDPA**

<table>
<thead>
<tr>
<th>Skill Area</th>
<th>Correlation between skill area and total test score</th>
<th>Alpha if item deleted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posture - supine</td>
<td>0.73</td>
<td>0.86</td>
</tr>
<tr>
<td>Posture - prone</td>
<td>0.71</td>
<td>0.88</td>
</tr>
<tr>
<td>Reach - supine</td>
<td>0.67</td>
<td>0.89</td>
</tr>
<tr>
<td>Reach - prone</td>
<td>0.77</td>
<td>0.88</td>
</tr>
<tr>
<td>Reach - sitting</td>
<td>0.53</td>
<td>0.89</td>
</tr>
<tr>
<td>Grasp - dowel</td>
<td>0.88</td>
<td>0.88</td>
</tr>
<tr>
<td>Grasp - block</td>
<td>0.82</td>
<td>0.88</td>
</tr>
<tr>
<td>Grasp - pellet</td>
<td>0.64</td>
<td>0.89</td>
</tr>
<tr>
<td>Manipulation</td>
<td>0.83</td>
<td>0.88</td>
</tr>
<tr>
<td>Release - block</td>
<td>0.72</td>
<td>0.88</td>
</tr>
<tr>
<td>Release - pellet</td>
<td>0.32</td>
<td>0.92</td>
</tr>
</tbody>
</table>

N=30
correlation coefficients (ICC) were calculated from the following formula (Shrout & Fleiss, 1979):

\[
\text{ICC} = \frac{\text{BMS} - \text{EMS}}{\text{BMS} + (k-1) \text{EMS} + (k(\text{JMS} - \text{EMS})) / n}
\]

where BMS = between-subject mean square
EMS = error mean square
JMS = observer mean square
k = no. observers
n = no. subjects

This coefficient is a measure of true agreement and represents the relationship between true variance and error variance in the scores. Coefficients were calculated for the total scores on the EDPA and for the scores on each of the five skill categories; these values are shown in Table 8. The ICC for the total test was 0.88, which exceeds the criterion level of 0.75.
Table 8

**Intraclass Correlation Coefficients for EDPA by Skill Category**

<table>
<thead>
<tr>
<th>Skill Category</th>
<th>ICC Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posture</td>
<td>0.68</td>
</tr>
<tr>
<td>Reach</td>
<td>0.94*</td>
</tr>
<tr>
<td>Grasp</td>
<td>0.67</td>
</tr>
<tr>
<td>Manipulation</td>
<td>0.78*</td>
</tr>
<tr>
<td>Release</td>
<td>0.84*</td>
</tr>
<tr>
<td>Total Test</td>
<td>0.88*</td>
</tr>
</tbody>
</table>

* value exceeds criterion level of 0.75.

(n=20)

**Validity**

The authors of the PDMS suggest that scaled scores be used with handicapped children; however, these scores are not adjusted for differences in performance across children of varying ages, so can be used only to compare performance within individuals, and not across different children. There is only one set of scaled scores for all age levels. Scaled scores are therefore appropriate for use only on a test-retest basis to monitor progress over time. Percentiles and
age-equivalent scores could not be used in this study, since almost all of the children scored below the second percentile, and hence the scores on this test did not discriminate between the children in the study. The method chosen to calculate the scores on the PDMS was similar to that used to aggregate the EDPA scores. In each case, the total raw score on the test was divided by the total raw score expected for the child's age, yielding a percentage score. Adjusted ages were used according to the methods described previously (p. 18). For example, a five-month old child is expected to achieve a raw score of 54. If upon testing, the child obtains a score of 26, the percentage score would be 48. These percentage scores were then correlated with the scores obtained on the EDPA. The scores from 29 subjects were analyzed using Pearson's product moment correlation coefficient.

The correlation between the scores on the PDMS and the EDPA was 0.85 (p < 0.001). Figure 1 shows the relation between the PDMS scores and the EDPA scores for the 29 subjects tested.
Fig. 1. The total test scores on the EDPA and the PDMS for the 29 subjects.
DISCUSSION

Reliability

The results from the analysis of reliability suggest that the revised version of the Erhardt Developmental Prehension Assessment used in this study is a highly reliable measure of hand function. The high alpha coefficient calculated in this study is consistent with the idea that the EDPA is measuring a single construct, presumably hand function. The coefficient remains high as each skill area is deleted from the analysis, indicating that each category is contributing equally to the total test score.

The correlations between each skill area and the total test score (Table 7) do show that there are differences between the various areas. The grasp-dowel, grasp-block, and manipulation categories are very highly correlated with the total score, which could be interpreted to indicate that these skills are the most representative of hand function. Certainly, the test items in the manipulation category involve a variety of responses including, reach, grasp, and release, and represent a range of manual skills. The correlations for the reach-sitting, and release-pellet categories are lower, which may reflect a problem with the norms used for those test items.
An examination of the age norms used for release of a small object in other developmental tests including the PDMS (Follic & Fewell, 1983), the Bayley Scales of Infant Development (Bayley, 1969), the Denver Developmental Screening Test (Frankenburg & Dodds, 1970), and the Vulpe Assessment Battery (Vulpe, 1979) shows a wide distribution of ages, ranging from 10 to 23 months. On the revised EDPA, the child is expected to achieve this skill at 11-12 months of age. The age norms in the reach-sitting category on the EDPA are consistent with those used in other developmental tests, so it appears unlikely that the low correlation found between this skill area and the total score is due to inappropriate age norms. It may be that this category is evaluating different skills, such as trunk control, balance reactions and postural stability, which are not necessarily related to hand function.

The results also show that the revised version of the EDPA is highly reliable when used by different observers. The two observers who participated in this study had very different levels of clinical expertise, one with two months and the other with nine years of pediatric experience. The second observer was trained in two sessions prior to assessing the first subjects (see p. 29). The results show that even with a brief training period and diverse backgrounds, two observers can score this test reliably. The inter-observer reliability in this study exceeds the highest level of reliability (0.85) of the EDPA reported previously.
(Erhardt, 1982). It must be noted, however, that the subjects in this study were primarily developmentally delayed and hence showed patterns of movement that were delayed, but were essentially normal. This level of inter-observer reliability may be more difficult to achieve in a population of physically disabled infants, where more abnormal patterns of movement would be apparent (Berk & DeGangi, 1979).

It is also interesting to note the variation in the intraclass correlation coefficients (ICC) calculated for each of the five skill categories. The posture and grasp categories both have ICC values below the criterion level of 0.75. The inter-subject variability on the posture category was very small, presumably because the ceiling on this test is reached at 8 months. If the inter-subject variability is small, then differences between observers can easily lower the ICC (Kraemer & Korner, 1976). This lower ICC value may therefore reflect homogeneity among subjects rather than inter-observer variability. This is not the case for the grasp category. On this subtest, there was considerable inter-subject variation, suggesting that this category is more difficult to score reliably.

**Concurrent Validity**

This study also provides evidence of the concurrent validity of the EDPA, as assessed using the fine motor
scales of the PDMS. The correlation coefficient obtained indicates a high degree of relation between the test scores and exceeds the criterion level of 0.70 used in establishing the sample-size estimate. The coefficients obtained in this study far exceed those reported (ranging from 0.17 to 0.59) in a study of the concurrent validity of the PDMS with the Bayley Motor Scales (Palisano, 1986a). However, as approximately half of the items on the PDMS are similar, if not identical to items on the EDPA, it is important to determine whether the two tests are simply measuring the same aspects of hand function.

In order to examine how these two tests are related, as well as how they differ, the intraclass correlation can again be used. This statistic takes into account the slope of the correlation plot, as well as the absolute scores, therefore the correlation coefficient is adjusted for the difference between the scores (Kramer & Feinstein, 1981). Because both the EDPA and the PDMS scores are expressed as percentages, the absolute scores can be compared. The ICC that results is 0.53, showing that the tests are related, but are also measuring different aspects of fine motor skills. A higher ICC would suggest that the tests were measuring the same functions.

When examining the individual scores on the two tests, a very consistent pattern of results emerges. The scores on the PDMS are lower than those on the EDPA for 26 of the 29 children tested. This discrepancy most likely reflects
differences in the content of the tests, as well as in the scoring methods. The PDMS appears to be a more cognitive test than the EDPA, in that on many of the items on the PDMS the child must be able to imitate or follow verbal directions and is often required to complete a specific task (Folio & Fewell, 1983). These tasks may themselves involve other skills such as shape or size discrimination, spatial organization and sequencing ability. Similar test items on the Bayley Scales of Infant Development (Bayley, 1969) are included in the Mental rather than the Motor Scale.

The three children who achieved higher scores on the PDMS may have been functioning at a cognitive level more appropriate for their chronological ages, but were more physically or motorically delayed. One child was hydrocephalic, one had achondroplasia, and one was premature. The latter two conditions are less frequently associated with cognitive impairment than Down's syndrome (Dutton, 1975; Wyne & O'Connor, 1979). None of the Down's syndrome children obtained higher scores on the EDPA.

The EDPA is an observational test in which materials are presented to the child and patterns of movement are observed during undirected play. If a pattern component is observed, the child is given credit on the EDPA, whereas the criteria for passing an item on the PDMS are much more stringent. The children are given instructions only once and
are expected to complete the task in a particular way (e.g.,
Item 44: Place four cubes and cup before child. Say "Put the
cubes in the cup." Criterion: Places three cubes into cup.)

These different scoring methods reflect the nature of
the two tests. The PDMS is a quantitative test in which
children either pass or fail an item based on some specified
criterion. The EDPA is a qualitative measure of hand
function, focusing more on how children perform a particular
activity, than on whether they complete a specific task.
Both the EDPA and the PDMS attempt to evaluate hand
function, but each has a different focus. These two measures
therefore complement each other in the evaluation of hand
function in the young child.

**Discriminative Ability of the EDPA**

One of the objectives of this study was to develop the
EDPA further as a discriminative measure. Despite the high
levels of reliability and validity reported here, there are
a number of factors in the design, content and
administration of the test which may limit its
discriminative power.

An examination of the content of the test suggests that
the EDPA is most discriminative for children aged between 3
and 10 months. For many of the skill areas the age ranges
for the test items are very limited. Of the 11 skill areas
in the test, only 6 have test items for children younger
than 3 months of age. The posture, reach and manipulation categories include patterns of movement and skill components that are observable in the very young infant, but the grasp and release categories do not. With further study of the development of hand function in normal infants, it may be possible to determine patterns of movement that occur prior to 3 months of age that form the basis for the later development of grasp and release patterns. Bower (1977) and DiFranco et al. (1978) have studied patterns of movement in young infants and were able to observe reaching and early preparation for grasping in children as young as 7 days of age.

At the other age extreme of the test, only four skill areas include items that are appropriate for children over the age of 10 months. These are: grasp of the pellet, manipulation, release of the block, and release of the pellet. Erhardt (1982) suggested that basic prehensile skills are acquired by the age of 15 months, and that beyond that point development is primarily reflected in changes in precision and speed of performance. The age norms used in the test would suggest, however, that most of these skills have developed by 11-12 months.

The scores attained by the subjects in this study support this argument, namely, that the EDPA does not discriminate differences in manual skills in children over the age of 10 months. The average adjusted age of the subjects was 11 months, and 20 of the 30 subjects were 12
months of age or older. The mean score on the EDPA for the 30 subjects was 77% (where 100% represents normal development), which is quite high given the developmental problems experienced by the subjects (see Table 2). The scores on the posture and reach categories were particularly high; the mean score for the posture category was 91.5, and for the reach category, 89.1. The posture items have an upper age limit of 7-8 months, and the reach items have a ceiling at 9-10 months.

One could argue that the children in this sample were not very severely impaired, and that that is the reason for their high scores. The results on the PDMS provide evidence to the contrary; 80% of the subjects scored below the 5th percentile for their adjusted ages. Palisano (1986b) supported the use of age-adjusted scores when evaluating motor development using the PDMS. Despite the cognitive aspects of the PDMS, it is primarily a test of motor development, and the results show that this group of children had significant motor problems. It appears that there are problems with fine manual skills in these children, but that they are not being detected by the EDPA. The restricted age range described for many of the skill areas limits the ability of the EDPA to detect problems in very young infants and in children over the age of 10 months.

On the summary score sheet, each child's score was graphed for the five categories. Despite the differences
among subjects in terms of diagnoses, level of function, and developmental status, the figures were remarkably similar. These graphs illustrate some of the previously mentioned limitations of the test, namely, elevated scores due to the early ceiling on some of the test items, and problems with the release category. For almost every child, the score on this category was considerably lower than for any other category. The group mean score for the release category was 56%, which is well below the mean score for the total test. It would appear that the age norms for this category are too high (p. 39). The results from the five normal children used in the pilot study would support this idea, as their scores were also below those expected for their age.

One section of the test that may be omitted from the test in future revisions is the manipulation category. This category is different from all other skill areas. In the posture, reach, grasp, and release categories, materials are presented and the child's responses are observed. In the manipulation category the child is expected to perform specific activities and the quality of the movement is less important. For example, two of the components included in the pattern "mouthing" are bringing a dowel to the mouth and sucking on the fingers. These represent specific behaviours, not components of a pattern of movement. The manipulation section is actually composed of a number of different activities rather than a developmental progression of one skill. These activities are similar to the items found in
the PDMS and in other scales of motor development (e.g., Bayley Scales of Infant Development; Denver Developmental Screening Test). The manipulation category does not assess the quality of movement, and replicates content from other tests, and so may not be included in future test revisions.

Researchers are attempting to develop assessments which are specifically directed towards evaluating manipulation. Exner (1987) has developed a test which assesses what she calls "in-hand manipulation". The test examines the child's ability to move objects between the fingers and palm, and to shift and rotate objects in the hand. She has collected pilot data on normal children and has begun to describe some of the components of manipulation (Exner, 1987). This test may give a clearer indication of manipulative skills than the EDPA, although it is designed for children aged between 18 months and 7 years.

Another section of the test that did not provide clinically useful information was reflex testing. As described earlier, reflex testing remained part of the test procedure, but the results were not included in the aggregate score. Reflex testing was attempted with the first 10 children with poor results. Their responses were inconsistent, and the instinctive grasp reactions and avoiding responses were never elicited. The children found the stimuli used to elicit these responses annoying, and frequently became upset, which interfered with the administration of the other test items. Because of their
questionable relevance, and unpleasant nature, reflex testing was dropped from the protocol. These items may be considerably more relevant in assessing children with neurological disorders where persistence of primitive reflexes is interpreted as a sign of the motor impairment (Bobath & Bobath, 1975).

A final area of concern about the content of the test, is the omission of items that seem important to the evaluation of hand function. Often during the test sessions, the children exhibited patterns of movement, such as atypical grasp patterns, which were not included in the scoring criteria. If children use atypical grasp patterns, they will not receive credit for that grasp item on the test. This raises one of the fundamental questions regarding developmental evaluations, particularly qualitative assessments. If the primary interest is in whether or not the child completes an activity then scoring is straightforward, but if one is interested in how the child performs the task, then one is faced with the impossible task of including in the scoring system all of the possible variations from a "typical" pattern that may occur. The sequence, rate, and characteristics of motor development in a child with a disability may be very different from those of a normally developing child, rendering any comparisons between the normal and impaired child meaningless. Norm-referenced assessments, so prevalent in the developmental
literature, are based on normal development and may not be appropriate for use with abnormal children (Missiuna, 1987).

In addition to problems in the content of the test, there are problems in the scoring system. A feature of the scoring system used in this revised version that may affect its discriminative ability is the credit given for items assumed to be present at earlier developmental levels. For example, a child of 5 months is expected to exhibit active midline control when placed in a supine position (i.e., head in midline, with shoulders depressed, reaching arms to midline, and opening hands). If the child demonstrates all of the components of this item, then a score of 2 (full credit) is also given to all of the skills in this category at lower age levels. This is based on the principle that development is sequential, and that the acquisition of a skill, such as midline control, is based on the child having achieved earlier milestones (Clark, Florey & Clark, 1985). This assumption may not be valid for children who are experiencing motor problems. Their development is not proceeding normally, so these children have not necessarily achieved earlier milestones. This would be especially true for children with a significant motor impairment such as cerebral palsy (Bobath & Bobath, 1975; Levitt, 1977). Longitudinal research is needed if we are to understand the development of hand function in disabled children. In assuming that earlier milestones have been achieved, the scores on the EDPA may be inflated.
A related problem involves the repetition of pattern components at different ages within a single category. For example, a component of the radial-pal grasp of the block at the 6-month old level is thumb opposition. This is also a component for radial-digital grasp at the 7-8 and 9-10 month levels, so that once thumb opposition is achieved, credit is given at all three developmental levels. This repetition is compensated for in part by the use of partial scores. If the child has demonstrated only the thumb-opposition component of radial-digital grasp, only one point is given. The repetition of components may, however, still reduce the discriminative ability of the items.

Kirshner and Guyatt (1985) state that a discriminative index should be comprehensive, tapping the important components of the domain of content, but at the same time consist of short response sets so that it can be easily administered. The EDPA is a difficult test to score because of the number of items in the test. Although the results show that the inter-observer reliability of the EDPA is high, the practical problems involved in scoring the test became obvious during the data-collection phase of this study. In order to achieve an optimal level of responding from the child, the examiner is required to position the child and materials, present the materials, sustain the child's attention, and monitor the child's responses carefully. With this young age group, it is very difficult to pause between items in order to score the test, which
means that the tester is obliged to remember the patterns of movement observed. There are 268 components listed as part of the assessment, and it is obviously not realistic for the examiner to remember all the possible responses that could be made by the child. A large number of components is necessary in an instrument designed to look at the quality of movement, but this makes scoring a very complex procedure. In addition, if the goal of the assessment is to discriminate between children, then the test is probably going to be administered on only one occasion. Results based on a single test session with a child can be difficult to interpret, particularly with infants, because of fluctuations in their emotional state and level of compliance. Scoring the test can also be a problem if the examiner is meeting the child and family for the first time. It is important to establish rapport with the child, and also with the parent. As the investigator in this study was also in the child's home for the first time and was a representative of the infant program, it was considered important to interact with the family during the assessment. These interactions can limit the examiner's ability to observe all of the child's movements and certainly to score the test. The estimates of interobserver reliability do not, however, support this assumption. For the 20 subjects who were involved in that aspect of this study, the investigator administered the test and interacted with the child and parent, while the second observer simply scored the test.
The high level of agreement between the observers may indicate that the investigator's scores were more accurate than anticipated.

Characteristics of the Sample

The characteristics of the children who participated in this study have, no doubt, influenced the results. As mentioned previously, most of the children were developmentally delayed, so showed delayed, yet primarily normal, patterns of movement. Their movement patterns are more likely to be included in the component descriptions than are the patterns of a child with a physical disability. For example, a child with cerebral palsy may show asymmetries in movement, increased muscle tone, associated limb movements, and atypical grasp patterns which would make scoring difficult and hence could reduce reliability (Bly, 1983).

Eighteen of the 30 subjects (60%) were diagnosed as having Down's syndrome, and so it is important to consider the characteristics of this group and how they may have affected the test results. First, there are a number of physical characteristics of Down's syndrome (DS) children which would affect their hand function. The actual structure of their hands differs from that of normal children in that they have short, broad hands, a single palmar crease, and shortened, incurved fifth fingers (Hook, 1982). Up to 80% of
DS children have hypotonia and hyperflexibility (Harris, 1984). The deficiencies in muscle tone may impair the DS child's general postural stability, and particularly the ability to stabilize the shoulder, elbow and wrist joints which facilitates accurate reaching and provides a base of support for refinement of grasp and release. The physical dimensions of the hand may interfere with the capacity to manipulate objects of various sizes, especially large objects. The homogeneity of physical characteristics in DS children may have produced consistent patterns of hand movements which would make the test easier to score, and hence more reliable.

Motor Development in Children with Down's Syndrome

The findings in this study support those in other studies (Carr, 1970; Harris, 1981; Piper, Gosselin, Gendron & Mazer, 1983) showing a decline in the rate of gross motor development over the first two years of life. As shown in Table 5, 93% of the children were able to roll at the appropriate age (5 months), whereas only 7% of the children were able to walk at the normal age. An analysis of the data from the DS children shows that 88% were rolling, 79% were sitting, and 58% were creeping at the normal age, but none of these children were walking at a normal age.

Rast and Harris (1985) disagree with the interpretation of the above findings, and suggest that the decline in the
rate of motor development is an artifact of the testing tools used. They hypothesize that there are significant motor deficits in the young DS child, particularly in early postural reactions, such as head righting, which are not assessed with conventional testing procedures. They also suggest that a test such as the Movement Assessment of Infants (Chandler, Andrews & Swanson, 1980) would be more sensitive to these problems than other developmental tests that focus on the achievement of motor milestones.

In the current study eight DS children were 12 months of age or less, and ten DS children were over 13 months of age. The average total score on the EDPA was 70.8 for the younger group and 81.3 for the older group. With this small sample of children, the results on the EDPA do not show a decline in the rate of fine motor development. The EDPA includes items that test early postural reactions, and so assesses the class of behaviours that Rast and Harris (1985) suggested would be impaired in the DS child. This may explain why a decline in the rate of development was not seen. It may, however, only reflect the problems with the lack of norms for the older age levels on the EDPA.

Recommendations

The aim of this study was to develop the EDPA further as a discriminative measure for use with developmentally and/or physically disabled infants. The results of this study provide evidence that the EDPA is a valid measure of
hand function, and that it has good inter-observer reliability. With reference to the criteria outlined by Kirshner and Guyatt (1985), Benson and Clark (1982), and Law (1987), this revised version of the EDPA has many of the properties of a good discriminative measure. It covers the domain of hand function and demonstrates excellent internal consistency. The procedures for administration are clearly stated, and the test is short, inexpensive, and places minimal burden on the children being tested. It can be used reliably by different observers and correlates highly with another measure of hand function. Based on this preliminary work, there appears to be value in continuing the process of test development.

This study raises several issues that require further investigation. It is important to test the construct validity of the EDPA, that is: Does this test discriminate normal from abnormal hand function? Prior to investigating construct validity, however, the EDPA should be administered to a large sample of normal children in order to verify whether the norms currently used in the test are appropriate.

In a revised version of the EDPA, many of the problems in the design of the test outlined above need to be addressed. In particular, the norms for children below 3 months, and above 10 months should be expanded based on the results from studies of the development of normal hand function. The manipulation section needs to be re-designed,
or dropped from the test because it evaluates very different types of skills from the other categories. Consideration must also be given to a way to account for earlier developmental milestones, and for the atypical patterns seen in the disabled child. The test should be used with other samples of children, particularly those with physical handicaps.

Practical problems still exist with the test in its present form. Although the administration procedures are simple and the test is quick, there are a large number of items, which are difficult to score in a single test session. Further investigation may lead to a short form of the test that can be used as a screening tool, and this more detailed version may be used as an evaluative measure to monitor progress on an ongoing basis.

The revised EDPA has many of the properties of a good discriminative measure and has the potential to become, through further refinement, an important tool for understanding both the development of hand function and the problems experienced by disabled children.
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APPENDIX 1

Consent to contact families
Halton Parent-Infant Programme

CONSENT TO EXCHANGE INFORMATION

CLIENT________________________

ADDRESS________________________

PHONE________________________

BIRTHDATE________________________

I understand that I hereby give consent to the PARENT-INFANT PROGRAMME, Halton Regional Health Department, 460 Brant Street, Burlington, Ontario to exchange information with______________

Nancy Pollock, B.Sc. O.T. (C)

I understand that this is required for the following reason(s):

to provide my child's name, date of birth and phone number so that he/she may participate in a research project as outlined in her letter of explanation that I received.

PARENT/GUARDIAN________________________

WITNESS________________________

DATE________________________

This consent remains effective for one (1) year unless revoked.
04/87
APPENDIX 2

Consent to participate in the study
I have been asked to allow my child to participate in a study that will see if an assessment called the ERHARDT DEVELOPMENTAL PREHENSION ASSESSMENT can measure the development of hand function in infants.

Nancy Pollock has explained to me that my child will be seen at home to be tested using two assessments, both of which involve observing how my child uses his/her hands to play with different objects. Sometimes a second observer will also be present. The tests should take about 45 minutes.

If I agree, the results of these assessments will be given to the infant development program to help them in planning my child's program.

I understand that my child's identity will be kept confidential in the study results and that I may withdraw my participation at any time. Withdrawal from the study will not affect the services that my child receives from the infant development program.

I agree to participate in this study.

CHILD'S NAME: ________________________________  PHONE NO. ____________
PARENT/GUARDIAN: ________________________________
WITNESS: ________________________________

I would like the test results to be given to the PEEL INFANT DEVELOPMENT PROGRAM

PARENT/GUARDIAN: ________________________________
WITNESS: ________________________________
DATE: ________________________________

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