THE USE OF PLAY ACTIVITIES IN ELICITING SPECIFIC COMPONENTS OF MOVEMENT IN THE DEVELOPMENT OF HAND-FUNCTION OF THE SPASTIC CEREBRAL PALSIED CHILD

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ABSTRACT

Factors relating to the normal and abnormal development of hand-function with the emphasis on feedback and the learning of movement, are discussed together with the rationale for assessment and treatment.

An assessment procedure was designed using parts of the Erhardt Developmental Prehension Assessment and additional items.

Twenty children were assessed, paired according to pertinent assessment results and randomly assigned to the balanced experimental or control groups. The children in the experimental group were given one treatment session of thirty minutes per week for twelve sessions with the emphasis on improving hand-function. All twenty children continued all other treatment, although in some cases an occupational therapy treatment was added for a child of the control group or omitted for a child of the experimental group to balance the total treatment received by the two groups.

Attention was given in treatment to the normalisation of tone, facilitation of automatic postural reactions, mobilization of the shoulder, stimulation of hand-opening and mobile weightbearing on the upper limb. Simple enjoyable activities were used to elicit 'normal' components of movement in the hand.

The only area that improved significantly more in the experimental group than the control group was selective finger movement as seen in handling of the pellet. A trend towards more improvement and less deterioration was seen in the experimental group in comparison with the control group.

Limited improvement is ascribed to insufficient emphasis on differentiation of movement at the shoulder girdle and on stabilisation of the shoulder and other joints of the upper limb.

DEDICATION

In Memory of my Mother

Dalene Rousseau

1910 - 1981

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ABBREVIATIONS

(Mainly used in Tables, Figures and Assessment Form)

A	– After
a	– arm
ā	– awareness
ADL	– activity of daily living
aff	– affected
appr	– approach
ass	– associated
ASS/R	– associated reactions
assmt	– assessment
ave	– average
B	– before
B Ave	– below average
bil	– bilateral
Br	– bright
c	– cube
C	– container
c̄	– with
CA	– chronological age
cm	– centimeter
CMC	– carpo-metacarpal
conc/concentr	– concentration
conv	– convergence
D	– developmental stimulation
decr	– decrease
Di	– diplegic/diplegia
diff	– difference
diss	– dissociation
distract	– distractability
dp	– distal phalanx
DSH	– dissociation of scapula and humerus
E	– Erhardt
e	– elbow
Ex	– examiner
exp	– experimental/experimentation
eye/p	– eye pursuit
F	– female
f	– forearm
g	– grasp
gc	– grasp cube
g/h	– glenohumeral
gm	– garment
gn	– generalisation
gp	– grasp pellet
Gr	– group
h	– hand
H	– hemiplegia
hemi	– hemiplegic
hum	– humerus
incr	– increase
ind	– individual
inf	– inferior
ip	– interphalangeal
IQ	– intelligence quotient

L - left
l - release
l1 - assistive release
l2 - above surface
l3 - into large container
l4 - into small container
L2 - second lumbar vertebra
lc - release cube
lp - release pellet

M - male
m - movement
mv - movement with vision
mx - movement of both hands
$\bar{m}$ / man - manipulation
$\bar{m}$l - manipulate with release
$\bar{m}$v - manipulate with vision
$\bar{m}$x - manipulate with both hands
mot - motivation for treatment
mp - metacarpophalangeal
mvt - movement

OT - occupational therapy

P - perception
p - position
pe - position of elbow
pf - position of forearm
pw - position of wrist
ph - position of hand
pt - position of thumb
propr - proprioception
PE / prot ext - protective extention
PT - physiotherapy

R - right
r - reach
react - reaction
rec - reciprocal
RMS - reciprocal movement of scapulae
Rx - treatment

s - shoulder
s1 - first sacral vertebra
scap - scapula(e)
sec(s) - second(s)
sev - severe/severity
SOT - scapula on trunk
ST - speech therapy
ster - stereognosis
sym - symmetry
sup - supination/supinated

t - thumb
TJ - teacher's judgement of intelligence
TOG - taking off garment
treatm - treatment

u - unaffected
UL - upper limb

v - vision
VBr - very bright

w - wrist

x - transfer

CHAPTER I INTRODUCTION

The candidate first became interested in the subject of the study while attending a neurodevelopmental therapy course in January/ February 1981. The integrating value of functional activity has always been a central aspect of occupational therapy. The key role of the upper limb in any type of function and the insufficient improvement of hand-function in many cerebral palsied children seemed to call for research in this area.

Occupational therapists have become increasingly aware of the extent to which the control of tone throughout the body of any cerebral palsied child dictates the quality of hand-function. However, relatively little work has been done about identifying other factors related to hand-function which could be incorporated in treatment and improve the dexterity of the hand.

One of the main goals of the occupational therapist is to ensure that the control gained during treatment is carried over into activities performed during the day. Hence, activity needs to be part of treatment. The normal and most frequently engaged-in activity for a young child is play and this is therefore the chosen medium for this study.

1. Hypothesis

Spastic cerebral palsied children treated by the use of play activity in a programme specifically designed to improve hand-function will improve more than children who are treated without the emphasis on improving hand-function.

2. Importance of the Study

The quality of hand-function influences all aspects of any individual's life. Hands allow the human being to become independent in personal care; to care for others; to take part in games or sport; to create; to earn a living and as an independent person to contribute to society.

The cerebral palsied child is often limited in some or all of these spheres due to lack of control, precision and strength of the hand. This influences the speed and efficiency of the execution of tasks which in turn influences the productivity and self-image of the individual.

Hand-function of cerebral palsied children has generally been found to improve together with control of the rest of the body. In many cases, however, in spite of this improvement the affected hand is avoided when dexterity or speed is required. Refinement of hand-use is therefore important.

Excellent progress has been made in the understanding of the components of movement in normal and abnormal development. Research has been done from many viewpoints on the learning of movement patterns. The development of hand-function as such has been studied. Feedback mechanisms have been investigated. All these and other factors need to be considered when dealing with hand-function.

It is the purpose of this study to:-

- attempt to identify some of the factors involved in the adequate hand-function of the normal child;
- attempt to identify and clarify factors influencing hand-function in the spastic cerebral palsied child;
- evaluate a method of assessing hand-function and related factors in the cerebral palsied child;
- evaluate treatment methods used in order to improve the specific problems identified in the children.

It is hoped that this study will provide some insight into hand-function and be a stimulus to work in a more directed way towards further improvement of hand-function.

3. Limitations of the study

The sample of twenty children was small.
In the absence of suitable standardized tests the assessment had to be developed or adapted for application in this study. During the

course of the period observer experience may have caused stricter re-assessment of function since finer variations from the normal were noted at the final assessment.

In an attempt to keep the outline of each treatment session similar for all subjects some freedom in the treatment situation had to be forfeited.

Because the children were in a special school there were many variables which could not be controlled. Two of the children, one in each group, had lengthening of the Tendon Achilles which temporarily affected their performance in hand-function. This setback was partly due to loss of treatment in both physiotherapy and occupational therapy as a result of absence from school.

There was a three week holiday in the middle of the period of treatment. Children may deteriorate during such a time because of lack of treatment.

The treatment was limited to one thirty minute treatment session per week for twelve sessions.

CHAPTER II LITERATURE REVIEW

The human hand can grasp, manipulate, feel and perform gross and fine motor tasks with "great strength, delicacy and dexterity" (Blacha, 1983a).

Achievement of the above is determined by many factors. Purposeful hand use requires co-ordination with vision. Accurate somatosensory feedback is important to adjust and grade grasp or manipulation. Precise movement patterns have to be learned until they become automatic. This learning requires attention to the task which involves the cortex. Even when patterns of movement have become automatic, the intention of performing the action still remains cortical. Since the hands are particularly suited to perform activities which are purposeful for each individual, it would seem logical to suppose that purposeful activity might be the best way of developing precise patterns of movement in the upper limbs.

Developmental and neurological principles influence all of the above. This will be discussed as follows:-

1. Normal development related to hand-function.
2. Abnormal development related to hand-function.
3. Assessment of hand-function and related factors.
4. Treatment of hand-function.

1. Normal Development

Normal development is difficult to define since "normal" implies variability. (Bly, 1981) The ability to use the hand for the many diverse tasks of precision and strength develops from many aspects simultaneously.

The use of the upper limb is integrally related to the normal position of the head in space, a stable trunk and good shoulder control. (Blacha, 1979) Achievement of control of movement is vital.

1.1. Basic mechanisms in the development of movement

- development - proximal to distal;
- development of postural tone;
- mass movement to selective movement;
- associated movements;
- excitation and inhibition;
- feedback.

Development - proximal to distal

For many years it has been accepted that development occurs in a proximo-distal as well as a cephalo-caudal direction. André Thomas (1960) points out that in approaching an object arm abduction/adduction at the shoulder joint dominates at first. This is followed by flexion/extension of the arm at the shoulder joint. Elbow movements are well developed by six months and are gradually co-ordinated with movement of the rest of the arm. Flexion/extension and ulnar deviation at the wrist become stronger and opposition of the thumb and index finger develop during the second six months.

Loria (1980) did a study with 12 full term infants of 30 weeks to determine whether there was any correlation between proximal and distal upper limb function. She looked at seven aspects of reach and eight aspects of grasp and found no correlation between the development of reach and grasp.

She therefore suggested that two motor systems operate during development of hand-function - 1) a proximal system controlling visually guided reaching and 2) a distal system controlling prehensile skill. She questions the principle that motor development occurs proximo-distally and that distal skills emerge from and are dependent on proximal control. She suggests further research into this hypothesis since it raises many other questions such as when and how the two systems become integrated, and whether they can operate independently (i.e. after damage to one system can the other still be effective?).

The development of postural tone

The newborn is mainly in physiological flexion especially at the ankles, knees, hips and elbows. In prone, in spite of physiological flexion, the child can extend his head against gravity and turn it to the other side. In supine the newborn cannot keep his head in midline. When pulled into sitting there is a definite head-lag. Bly (1981) concludes from this that antigravity flexion is different from physiological flexion and that antigravity extension develops before antigravity flexion. Irwin-Carruthers (1982 p. 7) confirms that "extension control develops slightly ahead of flexor control". Extension is important for stability, but antigravity flexion, especially from supine, is also very important for normal movement. Antigravity lateral flexion develops from the sidelying position. "Normal control of the head and trunk, therefore, implies the ability to extend in prone, flex in supine and laterally flex in sidelying". (Bly, 1981 p.85)

Mass movement to selective movement

Muscles do not work in isolation but are co-ordinated in patterns to perform movements. Even a small movement of, for example, the fingers, require a complex co-ordination of muscles. Movements at the wrist, elbow and other parts of the body need to be suppressed to allow precise movement of the fingers. The suppression of unwanted muscular activity is as much a part of movement as the activity of the muscles performing the movement.

Milani Comparetti (1967) points out that development of the normal child starts with undifferentiated patterns of movement which progressively become more selective and specific. To acquire selective patterns, the mass patterns have to be broken down into small units that can be combined and recombined to allow a wide variety of movement.

In writing programmes for a computer an experienced writer, in contrast to a beginner, will write no unnecessary programmes, just the necessary ones. Connolly (1970) suggests that children may increase their speed of performance in a similar way by cutting out unnecessary operations.

Connolly watched children of different ages putting pegs into peg-boards. He found that one of the most important developments that occurs is the refinement of temporal sequencing of the movements. Less redundance is seen - every movement counts towards the achievement of the whole task.

Associated movements

Connolly and Stratton (1968, p 49) described associated movements as "movements accompanying a motor or intended motor function but not necessary for its performance". The movements are mostly seen as contralateral and symmetrical to the limb or part of the body that is moving intentionally.

Abercrombie et al (1964) found statistically significant differences in both homolateral and contralateral associated movement between six and nine year old children.

Connolly and Stratton found that associated movement diminished with age, as seen in their study of children from four to fifteen years.

Excitation and inhibition

Gatev (1972) studied the inter-relationship of excitation and inhibition in motor co-ordination. In an experiment with children between one month and three years using electromyography to assess the activity of biceps and triceps the following was seen:-
- at one to two months - movements usually began without antagonist inhibition; (if elicited it was delayed).
- seven to nine months - antagonist inhibition was more frequent and better expressed but still imperfect;
- two and a half to three years - antagonist inhibition was well expressed. In most cases it was anticipatory due to the more exact interplay between agonists and antagonists. This allowed more precise and automatic control in movement.

He mentioned that later on in development agonist inhibition also develops. By the end of the third year it is present but still imperfect. The interaction between excitation and inhibition continues to be refined in the development of co-ordination in the child.

Feedback

Motor development is more accurately called sensory-motor development because of the importance of feedback through all sensory systems. A normal baby is very active and will repeat a movement again and again and thereby "develop an awareness of the sensation of the movements". (Bly, 1981 p 85). It is therefore important to know more about the mechanisms of feedback that enable a child to learn the feeling of a movement.

Feedback related to movement consists of:-

- internal feedback - this informs the nervous system of the intended action and can therefore also be called feedforward since it occurs before the action;
- feedback proper - this comes from the effector system and occurs during the action;
- knowledge of results - this can only occur after completion of the action.

When an object arouses the intention to act from the infant a discharge to the effectors causes the intended action to happen. Simultaneously a discharge is fired to the related sensory and co-ordination systems - this is a corollary discharge. This internal feedback makes postural and other adjustments possible during movement. (Bruner, 1973).

The sensory system concerned with feedback of movement is proprioception. This consists of 1) statesthesia and 2) kinesthesia.

1) Statesthesia is the perception of passive movement and appears to be dependent on joint receptors . (Jones, 1974). Bairstow and Lazzlo (1981) found the perception and memory of the "drawing" of complex, configurations to be better when the subject's limb was moved passively. This ability improves gradually and relatively regularly with development as seen in their study of children between five and twelve years. They, however, also found great variations in some subjects.

Statesthesia correlated with the ability to draw and write. It was not influenced by the intelligence of the child except in cases where the child could not understand the instructions. They also found that students who did ballet dancing and gymnastics had superior performance in the perception and memory tasks. They therefore concluded that this ability could be improved with practice. They did not, however, take into account that a superior ability in this area may have led these students initially to follow their line of study.
2) Kinesthesia is the perception of active movement and consists mainly of feedback by the muscle spindles.

Bossom (1974) also divides feedback into three categories:-
- corollary discharge - central signals which reflect the efferent signals to muscles during movement. This compares to Bruner's internal feedback;
- proprioceptive information (Bruner's feedback proper)
- sensory input experienced from the external world (related to Bruner's knowledge of results).

Bossom and his colleagues did various types of transsection of the dorsal roots of the spinal cord of monkeys which would destroy the proprioceptive feedback of the limbs. Movement in the upper limb especially of extensors and of grasp, particularly of the thumb, was most severely involved but could be retrained by the use of vision. Voluntary movement later became possible even without the help of vision. He concluded that proprioception may not be as indispensable as was previously thought but that corollary discharge could provide the needed feedback. Vision (the external sensory input) in his experiments was used to help the monkeys to initiate the "normal" movements and the corollary discharge made it possible for the monkeys to retain and repeat these movement patterns.

Apart from proprioceptive feedback the quality and usefulness of movement is also dependent on tactile feedback. Tactile exploration of their own bodies was seen in neonates during the first three days of life in the sequence of mouth, face, head, ears, nose and eyes. This was followed within the first ten months of life by the fingers, body, knee, foot and penis in that order, according to a study by Kravitz and his colleagues (1978).

1.2. Learning patterns of movement

Milani Comparetti (1980) talks about primary motor patterns (his name for primitive reflexes) which increase with functional needs and may recede later when that particular function is fulfilled. For each pattern there are moments (developmental dates) when they interact with other primary motor patterns. When one pattern overpowers other motor patterns the first pattern is called an organizer. When it recedes to allow other patterns to take over it is recessive.

According to Bobath and Bobath (1975) a child will sometimes practise a new pattern of movement he has learned for days or even weeks. Previous activities may be discontinued and even deteriorate as a result of the effort of learning a new and difficult activity. As soon as the new activity has become easy and established, earlier activities may be taken up again - frequently to become part of the new activity.

This is seen, for example, when the child starts walking. He holds his arms in abduction to maintain his balance as he walks on a wide base. The insecurity of this position (which is dominant at this stage) makes difficult the former rotation of the trunk and reciprocal movements of the arms which had developed when sitting safely on a stable base. Development of upper limb skills will only continue when the child is more secure in standing and walking. These will then be integrated with his newly acquired skills of standing and walking.

There are many hierarchical levels involved with voluntary activity. "All movements are made up of ensembles of contractions of individual motor units" (Popper and Eccles, 1977, p. 276). Every muscle is composed of many of these units. Impulses travel along a specialized nerve cell, the motor-neurone. The axon of this neurone branches in the muscle to terminate as motor end-plates to about a hundred muscle fibres. There are about 200,000 motor-neurones from the spinal cord that supply all movements, except head movements supplied by cranial nerves. An individual can even learn to activate individual motor-neurones. The most complex part of the loop is the motor cortex.

When a person wills an action a "readiness potential" gradually builds up over a relatively large part of the cortex. The cortex may initiate and continue voluntary movement but accurate movement is dependent on the cerebellum.

Throughout life the cerebellum is engaged in a continual learning programme. As impulses are sent down the pyramidal tract collaterals go to the pars intermedia of the cerebellum and feedback occurs to the cortex to modify impulses as needed. The pyramidal tract continues distally. Receptors in skin, joints and muscles then signal back to the cortex.

As an individual learns a movement initially it is done very slowly since it is not yet preprogrammed. As the movement is practised more and more of the movement is preprogrammed and the movement can thus be done with more speed.

Trained movements seem to be mainly preprogrammed. Exploratory movements seem to be imperfectly preprogrammed since they are provisional and may continually be revised. Preprogramming occurs through the pre-motor association areas, the cerebellar hemispheres and basal ganglia while the parts intermedia of the cerebellum "updates the motor command" and continues to give feedback control to keep the movement "on target" (Popper and Eccles, 1977, p. 293).

The building of movement patterns

Connolly (1975) distinguishes between the terms movement, action, act and skill. The difference between a movement and an act is intentionality.

An action programme is made up of subroutines. A subroutine is a limited single act which must first be learned before it can be elaborated or incorporated in an action programme. Once an action plan is formed it can be refined by practice. Practice is not a repetition of the "means of solution" but rather of the "process of solving" of a motor problem. This means a repeated adjustment of technique to lead to perfection of the motor task. Once this action is performed automatically it, in turn, can become part of a larger and more complex action pattern (Bruner, 1973, p 3).

A skill may consist of several action programmes. Skilled activity is a programme of action directed towards the attainment of some goal. (Connolly, 1975).

Bruner notes (1973) that once the skilled act is performed and repeated successfully the whole act is reorganized using constituent parts in a new way.

Initially, in the development of hand-function for instance, the hand closes as the arm extends and the object is touched with the closed hand. Later the hand would open, with hyperextension of the fingers, and only close as the object was touched. Repeatedly touching the object with the open hand leads to modification of the action pattern. Three aspects will be changed:-

- the anticipatory patterning will increase, this means the hand will gradually close to the shape of the object before rather than after it reaches the object.
- modularisation occurs - the timing becomes more exact and economical.
- the action is now replaced. This means that instead of pouncing on the object with both hands (six to seven months) the child will reach in two steps - first, extending his hand in the direction of the object, and then beginning to close his hand in anticipation of the size of the object. The previous pattern does not disappear but is still seen under stress.

This process is continually repeated. As soon as a new pattern is learned and repeated it becomes part (a subroutine) of a "higher order action". The environment triggers a response which leads to an adaptive, serially-ordered programme which reflects an internal principle of organisation. This whole process can be compared to the child's learning of words and then putting them together into phrases and later into more and more complex sentences.

When co-ordination is achieved between internal feedback, peripheral feedback and knowledge of results a subroutine needs less attention. As the subroutines are combined in more complex patterns more attention is available for the more complex activities. To achieve a serial order of events "feed forward" is necessary as well as this relative freeing of attention described above.

As the child's skill in tasks improves so does his ability to select and use the precise movement needed. This is seen in his more appropriate initial efforts when dealing with a new task (Bruner, 1973).

Goaldirected movement, therefore, can be seen as the combination of a series of "acts", becoming less variable but done with greater economy and more anticipation due to feedforward, feedback and the knowledge of results.

The role of attention in learning patterns of movement

Bruner (1970) believes the reason for modularisation - (the perfecting of an act which is then combined and recombined and varied in many ways) is attention. A new act takes up all available attention. In a study of young children Bruner found that during one particular week a pearl attached to a plaque held by one hand cannot be removed by the other hand but will absorb the child's attention completely for up to thirty seconds at a time. Yet the next week he will be able to remove this without effort in a few seconds. As soon as attention is freed a new pattern emerges. This new pattern may take one of three forms.

1) It may become a more inclusive activity with other parts similar to the original part. For instance, instead of taking an object in one hand while the other remains inactive, now the infant will take an object in one hand and then a second object in the other.

Instead of all the concentration being utilised for getting one object, it is now focussed on the intention of getting both. Usually, with the attention being distributed over a larger act, less attention is available for the original single act and the original act may initially be done more clumsily than before.
2) It may become a larger act with a more remote goal. (The single act will be included with other modularised acts). After the object is taken, for example, it may be placed in a container.
3) It may lead to breaking up of the initial act, with pauses in-between the parts, and then to a regrouping of these parts. When a cup is used initially there is a one-step transport of the cup-edge to the mouth. When this is achieved elaboration occurs like readjusting the surface of the cup and moving the head to meet the cup. Then the interaction of adjusting the cup and head is monitored all the time and occurs as a smooth sequence (Bruner, 1970).

Developing control of movement

The central nervous system (CNS) consists of several billions of synaptic connections. Each neuron receives excitatory and inhibitory impulses continuously. Whether it fires or not depends on the balance of inhibition and excitation. Inhibitory control has to be continuous to prevent involuntary muscle activity. Activity in anterior horn cells is maintained just below the threshold of excitation by inhibition. Voluntary activation is sufficient to fire the neuron into action (Kottke, 1980). The learning of even a simple motor response "involves a complex patterned operation in millions of neurones, the socalled engram" (Karczmar and Eccles, 1972, p44).

A motor engram according to Kottke (1980) is formed by linkages between neurones, as they are repeatedly activated together to perform a pattern of movement in a "specific sequence of speed, strength and motion". This also entails inhibition of other neuronal pathways so that muscles not involved in the specific movement are not activated. The engram pattern can only be precise if the movement pattern has been done precisely.

The most important aspect of developing an engram of co-ordinated movement is the development of inhibition so that the muscles that should not take part do not.

Starting with primitive crude patterns gradually new patterns are "modelled" and "chained" (Kottke, 1980) and muscle movement becomes more refined.

It is rewarding to the child to recognise that he has control of a pattern of movement. He therefore continues to practise this pattern to get the sense of successful performance. This practice leads to the development of an automatic engram. As his performance is perfected he no longer needs to attend to the activity so much and is therefore no longer rewarded so he discontinues the practice of this pattern and begins with something new or more complex - something that "challenges his ability to perceive and control" (Kottke, 1980, p.555). The engram is thus preprogrammed and automatic and is available in the extrapyramidal system.

When an engram, for example, of a movement has been formed, it can be activated, continued, and or discontinued by the volition of the person performing an activity. As these movements are practised, engrams are chained and, switching from one unit of engrams to another, becomes more automatic.

<u>Intention and the learning of movement</u>

Voluntary movement is initiated by the intention of the person wanting to perform the movement (Bruner, 1973). Intention has some measureable features, namely:

- anticipation of the outcome of an action;
- selection amongst other appropriate solutions to achieve the intended result;
- sustained direction of behaviour during the action;
- stopping when the end state has been reached;
- correction of any deviation.

Arousal in the infant initially leads to orienting to the stimulus and some anticipatory behaviour. Sometimes this is followed by "a loosely ordered sequence" (Bruner, 1973,p.2) of movements which are at a later stage organised to achieve the outcome of the intention - first in a rudimentary way, then later in a more refined way. This is seen, for example, in the prolonged looking of the infant towards an interesting object which is at the correct distance. After this there may be movement of the mouth, tongue and jaws. Then ballistic flinging of the clenched fists may start. At this stage these acts or subroutines do not yet occur in the right order but they are all acts that will eventually lead towards the attainment of the goal.

Eventually these acts are correctly ordered; and the act of attaining the object and bringing it to the infant's mouth is achieved. This results from the combination of the maturation of the nervous system and the practice of the infant (Bruner, 1973).

An intention can be achieved in various ways depending on the requirements of the activity to be done. Juggling two balls does not leave much room for variation since they have to be dealt with at high speed and in a specific way. But when splicing or tying a rope, a greater variety of serial orders will still lead to the required objective. This means that a "developed skill has 'rules' that include appropriate variant orders and exclude inappropriate ones" (Bruner, 1970, p.65).

The 'secret' of smoothflowing action is a sense of what one is doing now and anticipation of what is coming next to fit into the objective of the activity performed. "The crucial issue in the regulation of intentional action is the opportunity to compare what was intended with what in fact resulted, using the difference between the two as a basis of correction" (Bruner, 1970, p.67).

Harrison (1975) points out that in combining motor programmes in the short term the important factor is whether the subject can 'compose' a movement programme adequate for the task. In the long term, however, the most important factor is whether he can carry over into new tasks any of the movement programmes which he has learned.

Learning through play

The development of hand-function cannot be understood fully without looking at the child's play in the first year of life.

This includes problem solving where:-
1) the intention is held constant while various means of attaining it are tried out;
2) the intention is changed to fit available means and means and ends may interchange. (Bruner, 1973)

The latter could be called mastery play - "playful means-end matching". This consists of the extension of skills already learned. When the six month old baby has learned to hold an object and gets it to his mouth, he starts varying his activity. He may look at the object, shake it, bang it, drop it over the edge and try endless variations with this object. At the same time as soon as he has mastered a sensory-motor task like holding an object with one hand while exploring it with the other hand, he will try this activity with every possible object.

1.3. Steps in the development of hand-function

Because of the importance of hand-function, the development of prehension has been studied by authors of many different disciplines. As early as 1915 Myers described in detail the development of hand-function of one child over the first year of life. Halverson's study of prehension of infants by means of systematic film records in 1931 has been used by many subsequent authors (McGraw 1941, Cliff 1979, Loria, 1980, Erhardt, 1982) as a basis of their investigations.

He originally analysed prehension in terms of regard, approach, grasp and disposition. The latter includes manipulation and release.

Regard

Reaching with the eyes is an important aspect of regard. Infants must "reach" with their eyes before they can meaningfully reach with their hands. This follows the normal cephalo-caudal trend of motor development (Cliff 1979).

Ammon and Etzel (1977) described visual responses in their developmental model under the headings : attention, pursuit and hand regard.

. Attention develops within the first three months sequentially as follows:-

- attention is distracted by all objects in the visual field due to poor head and trunk control;
- an object on the side of the favoured tonic neck reflex is glanced at briefly;
- when fixating an object the child appears unable to turn away from it. Following this, however,
- the child may alternate his attention from one object to other objects;

. Pursuit develops within the first three and a half months in the following sequence:-

- peripheral pursuit - the child follows an object outside his focal distance in a jerky way, lagging behind, but he can follow for 180^0. Kremenitzer et al (1979,p.444) described this as "brief segments of smooth pursuit interspersed with saccadic eye movements". Saccadic movements are "brief flicks" of movement normally used in scanning the environment. In their study of neonates, increasing the speed of the moving target decreased the ability of the neonates to use smooth pursuit movements. Even at the lowest speed smooth pursuit was used less than fifteen percent of the time. The movements were mostly in the direction that the target moved but at times they were also in the opposite direction.
- central pursuit to 90^o. The child can then fixate an object at nine to twelve inches and follow it for 90^o. He leads rather than follows the object with his eyes. This ability is essential before the development of visually directed prehension can take place.
- central pursuit to 180^o can then be achieved as close as six inches from the nose, since he has by now learned to focus on objects close to his eyes.

. Hand regard develops within the first seven to eight months step by step as follows:-

- attentive looking at the hand in the tonic neck reflex position;
- mutual tactile exploration of the hands at midline;
- regard of his clasped hands at midline or watching as he brings them together and explores them tactually;
- regard of the environment - good fixation on objects as well as on his hands.

Primary and secondary visual systems can be identified in the development of regard. Bronson (1974) postulates that the baby during the first month of life uses a more primitive secondary visual system which is gradually replaced during the second and third months by the primary visual system.

Because of the immaturity of the macular area the neonate uses peripheral vision. He is, however, able to track a moving visual target and to move his eyes to another peripheral stimulus.

Around the second month the macular area develops sufficiently to allow the infant to focus his attention on elements within foveal vision. He begins to encode some elements and begins to form associations with them.

Around the third month he becomes able to examine various aspects of a stimulus during a series of refixations. Because of this he now becomes able to encode entire patterns whereas before he could encode only isolated elements. He now smiles at a face, not just at the eyes. Because of the development of visual memory the infant uses his vision more and more in purposeful regard.

The focal distance also affects regard. White (1978) confirms that the baby can only focus close enough to see his hands (five to six inches from his eyes) by the third month. It can be as early as seven to eight weeks but often not until four weeks later. At first the baby may notice the hand passing in his field of vision and look after it. Gradually he spends more time looking at it, sometimes for long periods - up to ten minutes at a time. By three and a half months the baby can focus his eyes for all distances. He is actually better at focusing near distances (three to four inches) than the normal adult since his eyes are closer together and he can thus more easily turn both eyes in towards a very close target. By three and a half months he can converge well and his visual ability is nearly mature . At this time the hands are also less often in a fisted position. They begin to open and fingers start moving, which makes them much more interesting to look at. The baby is very curious at this stage and if presented with a small attractive object within his reach he will 'swipe' at the object.

Looking also becomes exploring. He looks at faces or pictures of faces and small detailed objects as well as moving objects, all still within two to three feet away.

Some children at six months will start staring at small particles, like crumbs, since their visual ability enables observation of more detail at this stage.

In the process of regard, vision and touch are closely linked. Bower and colleagues (1970) experimented to ascertain whether vision precedes touch or vice versa when object size, shape and hardness are determined by the child. Three conditions were created - grasping an object out of sight - tactile; grasping an object seen - visual - tactile and grasping a 'virtual' object seen but not substantial - visual. To achieve the latter the image of an object was projected to appear to the child as a solid object within reaching distance.

Hand shaping in anticipation of the shape of the object presented visually occurred in all infants (from six days to six months). The authors concluded that vision is dominant over touch even in early development. They found that vision is an anticipatory system which prepares the hand for grasping, and that touch took over once the object was in the hand.

However, Loria (1980) pointed out that at thirty weeks visual guidance is not enough to enable the child to orientate his thumb for grasp. Tactile input is needed to call forth the thumb action. Later in development when more integration of the sensory systems has taken place, the correct thumb position can be employed using vision alone.

Regard is an essential stepping stone in the development of eye hand co-ordination. White describes how the various action systems become co-ordinated. At first an object may be placed within the child's hand without his really being aware of it. By two months he may swipe at an object he sees within his reach. By two and a half months when an object is placed in his hand he will look at it and bring it to his mouth. Grasping, looking and sucking have become co-ordinated (White, 1978).

Swiping at objects can be very accurate or may overshoot the target. This is the first step in the co-ordination of eyes and head with the arms. Grasping at this stage, according to White, is not related to vision but is exclusively elicited by tactile stimuli. After this the hand will be raised to within an inch or so of the object and glances will alternate between the hand and object.

Between three and four months as the child grasps his hands mutually, tactile-motor development continues. The grasp reflex and Asymmetric Tonic Neck Reflex (ATNR) are no longer active. The baby begins to watch his hands while he feels them. When an object is brought within the visual line of the baby he will fixate the object while clasping his hands and later he may reach at it with clasped hands to bring it to his chest. (White, 1978)

Even when an object is placed in one hand he will bring it to midline and bring the other hand to it to finger it, exploring it with both hands. Apart from tactile exploration he will also bring objects to his mouth to be explored. A four month old baby will hold a rattle but not look at it.

Between four and five months alternating glances lead one hand slowly to the object where it fumbles and slowly grasps the object. The visual motor schemas of eye-hand and eye-object have now become integrated with the tactile-motor schemas of the hand. This is the beginning of visually directed grasping. By the end of this period the child can bring his hand from outside the visual field to an object and can open his hand in preparation for grasping the object. He has attained "top level" reaching (White et al, 1964).

Bower (1974) distinguished visually initiated from visually directed and visually guided reaching. The sight of the object stimulates reaching initially but no adjustment is made during reaching. In visually directed reaching the child looks alternately at the hand and the object and the movement of the hand is adjusted as needed. Although visual control is available by 26 weeks, it is no longer necessary. When the child is shown an object and the lights are put out he can still reach the object with great accuracy. Reaching has become visually guided.

Horton (1971) considers the period from five to nine months to be vital in the development of eye hand co-ordination. Even as the child begins to grope for and rake the object, he watches it intently. After nine months such intent visual regard is only seen (to the same extent) with new or difficult tasks.

After the initial mastery of eye movements and other visual skills, further development is closely tied to the development of visual perception. (Gesell and Amatruda, 1974).

Eye movements continue to develop as the child matures. The control of a ten year old child is better than that of a six year old child. Swift and accurate eye movements bring the important section(s) of a visual area to the fovea while other parts are perceived by the peripheral areas of the retina (Abercrombie, 1970).

Approach

Halverson (1931) further considered in this, his second component of prehension, whether the approach or reaching of the infant was bilateral or unilateral; the angle of the elbow and position of the forearm; the directness of the approach and the vertical profile of the approach.

The development of reach (approach) and its close relationship with regard is described above. In younger infants the hand is a "reflex grasping tool at the end of a directing upper arm". (Halverson, 1932, p.35). Later the index finger and thumb lead in reaching and grasping.

The influence of the ATNR causes arm movements during the first few months to be mainly unilateral. After sixteen weeks the head is more in the midline and bilateral arm movements are more frequent. From twenty eight to thirty weeks arm movements may again tend to be unilateral (Cliff, 1979).

A further development of reach is crossing the midline of the body. Irwin-Carruthers (1982) points out the importance of central control of the head and trunk before the arm can be brought across the body's midline. The child needs to be able to cross the midline of his body with his upper trunk rotated on his pelvis, before he will spontaneously cross his midline with an arm.

Provine and Westerman (1979) tested 51 infants between nine to eleven weeks and eighteen to twenty weeks by restraining one arm under the blankets and observing reaching behaviour ipsilateral to, at midline and across the midline. Thirtythree percent of the youngest group were able to touch the midline and this gradually increased to a hundred percent by eighteen to twenty weeks. Crossing the midline was observed earliest in one child of twelve to fourteen weeks. This gradually increased until all the children at eighteen to twenty weeks could touch across the midline. They, however, admitted that the restraint of the other arm elicited this behaviour earlier than would normally be observed.

Grasp

The thumb and index finger play a leading rôle in grasp. The thumb is controlled by four extrinsic muscles and six intrinsic muscles which are supplied by the radial, ulnar and median nerves (Flatt, 1961).

This digit is capable of great mobility as well as stability. The carpo-metacarpal joint is a synovial saddle joint with two principal curvatures. Each surface is concave in one plane and convex in the other (Kapandji, 1970). The radio-ulnar curvature is virtually congruent; the dorsi-palmar section has a wide disparity between the two bones. Whereas the distal surface of the trapezium has a lesser curvature the curvature of the metacarpal base is more extensive. The ligaments are lax.and the joint is very mobile in the midposition. In full abduction or adduction of the thumb, the surfaces are congruous due to the concave/convex surfaces "locking" in position at either edge of the radio-ulnar plane. The ligaments are tense and the joint is very stable. Full abduction is used for precision and full adduction for power grips.

The longest axis of straight flexion/extension in the thumb is in a horizontal plane. The longest axis of the other four fingers is in a vertical plane. This enables the thumb to place its volar surface into full opposition to the volar surface of each of the other four fingers by circumduction (Napier, 1955)

In addition to greater range in flexion/extension and ab-/adduction compared to the other phalanges, the index finger is also capable of some circumduction.

In order to grasp different objects the hand must be able to change its shape. When grasping a flat object the hand can flatten out, but to grasp round objects the hand has three arches. The carpal arch corresponding to the cavity of the wrist and the metacarpal arch which is parallel and distal to the carpal arch are both transverse. The longitudinal arch consists of the carpo-metacarpophalangeal arches commencing at the wrist and extending along each finger. The metacarpophalangeal joints are the key stones of these arches. When there is a muscular imbalance at this joint the arch is affected. (Kapandji, 1970).

Halverson(1932) pointed out that the crease lines of the palm of the hand give an indication of how the fingers cooperate, pointing to adduction of the thumb, approximation of the thumb and index finger and flexion of the three ulnar fingers.

Napier (1956) divides mature grasp into two fundamental types - power grip and precision grip.

- Power grip is a grasp between partly flexed fingers and the palm with counter pressure applied by the thumb, seen, for example, in holding a hammer.
- Precision grip is a grasp between the flexor aspect of the fingers and the thumb.

He shows that it is not the shape of the object, but the function required that determines the grasp used. This can be seen by starting to open a lid which requires a power grip and as the lid gradually unscrews a precision grip is used more and more.

The fundamental difference between these two grasps is the position of the thumb. In the power grip it is adducted in both carpometacarpal (CMC) and metacarpophalangeal (MP) joints. A grasp can be partly precision and partly power depending on the needs of the activity, but one aspect will predominate at any one time to determine the position of the hand.

When power is required the thumb is wrapped over the other fingers to reinforce the grip. When precision is required the thumb is abducted and medially rotated at both the CMC and MP joints to be in opposition to the other fingers. In a precision grip the palmar surfaces of the fingers and thumb are positioned to give maximum sensory information (Flatt, 1961). This enables fine adjustments of opposition to meet the specific functional need. (Napier, 1956) When tools are used, generally speaking the tools are directed towards the radial side when speed and precision is required and towards the ulnar side when slower and more powerful activity is required (Flatt, 1961).

The child starts with reflex behaviour which gradually develops into voluntary prehension. In the very young infant a stimulus is followed by an immediate output. Later when the system is more stable the output may or may not follow. There is an increase in the degree of freedom, for example, to grasp or not to grasp. (Prechtl, 1977)

Horton (1971) points out that the infant's ability to reach forward develops at the same time as his grasp becomes less reflexive and more voluntary.

The time required to grasp decreases with the maturity of the child. Halverson (1931) analyzed the following aspects:-

- the time required to grasp the cube after reaching it;
- the distance the cube is displaced before it is grasped;
- the number of times the hand is readjusted before the cube is grasped.

Although the time required to grasp the cube decreased from 1,5 seconds at twenty weeks to 0,5 seconds at fifty two weeks, the amount of time taken to grasp was influenced by the development of new types of grasping. Each time a new type of grasp was used the time would be slightly increased and would then decrease again with more dexterity. He also found that the younger infants (twenty to twenty four weeks) tended to use their shoulder alone in lifting the cube while children from twenty four to fifty two weeks tended to use elbow flexion with forearm rotation.

Kopp (1974) points out that although different children may show the same level of grasp pattern, the way they achieve this may be very different. The quality of movement, therefore, distinguishes the well integrated from the poorly integrated child. The clumsy child may need to attend more to his movement or to repeat movements in order to achieve a goal. The better integrated child can attend to the object and therefore show a wider repertoire of movement possibilities in relation to the object.

Gesell and Amatruda (1974) distinguished the following types of grasp:-

Grasp of a larger object such as a cube:-

- palmar (24 weeks) - fingers against the palm. This may include flexion of the wrist;
- radial palmar (28 weeks) where grasp includes the thumb;
- radial digital (36 weeks) where grasp is between the thumb and fingers.

Grasp of a smaller object such as a pellet:-

- raking (28 weeks);
- inferior scissors (32 weeks) - the thumb is adducted against the curling four digits;

- scissors grasp (36 weeks) between the thumb and curled index finger;
- inferior pincer (40 weeks) between the ventral surfaces of the thumb and index finger, resting the arm on the table for stability;
- neat pincer (48 weeks) - a pellet is grasped from above precisely between the finger tips.

Lawrence and Kuypers (1968) found in their study with monkeys, that two separate brainstem systems were involved in the control of proximal and distal limb movement.

Geschwind, 1975, believes that the pyramidal system controls movements of fine dexterity of the opposite side whereas the non-pyramidal system controls axial muscles on both sides - ipsilateral and contralateral.

The reason why the radial part of the hand becomes involved relatively late in grasp may be due to the extent of control exercised by the cerebral cortex on this part of the hand. Halverson wondered whether this might be the reason why the radial digits do not participate to the same degree in the more automatic movements of the younger infant. Blacha (1983b) hypothesized that the transition between the "noncortical and cortical grasping mechanism" occurs when the index-finger becomes involved in grasp.

Halverson (1932) distinguished three stages of grasping:- The "palming" stage (0 to 24 weeks), "intermediate" stage (24 - 36 weeks), and the "digital grasp" stage (36 weeks and older).

Hohlstein (1982) in her study of the development of grasp used Halverson's three stages and referred to them as developmental phases, namely:-

- use of the whole hand in an unspecified way;
- use of part of the hand as some specialisation begins to develop;
- use of the tips of the fingers or the pads of distal phalanges in a specialised way.

Phase 1 was characterised by extension and abduction of the fingers - during the approach to an object and by total flexion and adduction as the object was grasped. (At this stage the infant is often still unstable in the upright position or is just beginning to develop shoulder stability)

In phase 2 children have developed stability in their shoulders and elbows. They do not use the hand any more as a whole but are not yet able to use "precisely isolated movements".
In phase 3 children have developed stability of the shoulder, elbow, wrist and carpal metacarpal joints.

She identified eleven descriptive categories in addition to ten used by Halverson. These could all help to distinguish and judge the quality of grasp more precisely.

Horton (1971) noted that when the child is able to isolate movements of the index finger, fine prehension begins to develop, progressing from the scissors to the pincer grasp. Poking by the index finger may give the normal child the tactile and proprioceptive input needed before grasp becomes possible (Rast, 1984b).

During the second year of life grasp continues to develop. The fingers are less frequently used as a unit as they become freer. The child begins to oppose other fingers to the thumb as he manipulates small objects. Even the whole-hand grasp becomes appropriate with opposition of the thumb whilst the carpal and metacarpal arches are moulded to the shape of the object. During the third year further refinement occurs and the dynamic tripod grasp begins to develop.

Rosenbloom and Horton (1971) studied the development of the dynamic tripod grasp in 128 normal children between one year eight months and seven years. The earliest grasp of a pencil noticed was a supinated one - shortly afterwards this would be replaced by a pronated grasp. The thumb is parallel to the index and middle fingers. The child continuously readjusts the pencil with the other hand and he holds the pencil at its proximal end. Gradually from two and a half years the grasp moves distally on the pencil and the thumb becomes opposed to the radial border of the terminal phalanx of the middle finger.

At first the child tends to write using predominantly shoulder movement. Gradually the elbow, wrist, and finally the metacarpophalangeal joints become the focus of movement. By about four to six years localised movement consisting of minute movements of the interphalangeal joints is seen. The fourth and fifth fingers become more and more reinforcers for the middle finger and thus give stability to the dynamic tripod.

While there is no intrinsic muscle activity this grasp may be called the tripod. This, however, develops into the dynamic tripod by the time movement occurs at the interphalangeal joints.

Connolly and Elliott (1972) studied the use of tools by forty nine nursery school children between two years ten months and four years ten months. The use of a paint brush in unrestricted unrepresentational painting was observed for ten minutes for each child and four parameters, including grasp, were analysed. Seven distinct types of grasp were identified - adult grip, adult clenched, ventral, ventral clenched, oblique palmar, transverse palmar and transverse digital.

When these grasps are compared to the classification of adult grasps by Napier difficulties in exact classification are seen since they vary from the adult grasps and some of them would possibly be seen more as a composite grasp by Napier. The transverse digital, adult and ventral grasps all allow a relatively high level of finger control whereas the other four lack control.

The commonest grasp seen in their study, the adult grip (74,8%), involves true opposition of the thumb and moderate finger flexion and was seen with increasing frequency on maturation. The younger children tended to use grips involving clenched fingers. This decreased in favour of grips with more precision in older children.

Manipulation

Manipulation continually matures, becoming more controlled and more complex. This progresses from simply holding an object being looked at in the hand, to mouthing, shaking, banging, transferring, matching of two objects, putting one object on top of another or into another, aligning objects, fitting them together and many other complex combinations.

Whenever the child is faced with a new function he reveals its newness by awkwardness in execution; whereas his performance becomes smooth as soon as the function is integrated into his action pattern system (Gesell and Amatruda, 1974). The way of holding a cube differs in younger and older children. The younger child will have a vice-like grip of the cube holding it in the palm of the hand and not moving it in the hand. The older child will hold it with just enough pressure to prevent it from falling, holding it in the finger tips and changing the grip to manipulate the cube with their finger tips (Halverson, 1931).

Elliott and Connolly (1984) classified manipulative hand movements into simultaneous movement patterns (including simple synergies and reciprocal synergies) and sequential patterns of movement. Under each of these, further patterns of movements were described and illustrated by specific simple activities. A further help to descriptive analysis was an exact definition of the axes and possible positions of the open hand.

Examples of simple synergies were pinch as in removing splinters, dynamic tripod as used in writing and squeeze as in the use of a syringe. Reciprocal synergies included twiddle as used in unscrewing or screwing a nut into a bolt; rock which involves taking off or putting on a screw top; radial roll as used in winding a watch; index roll as used to make a small plasticine ball between the thumb and index finger; and full roll as used when rolling a bigger object.

Sequential patterns included rotary step, used when turning over an object in the hand; interdigital step used to turn a pen end over end; linear step, as seen when sliding the hand steplike along a long thin object; palmar combination as used in tying knots and palmar slide which is seen when removing the top of a pen.

Some of the examples are not self evident. Few individuals would, for example, use a radial roll to wind a watch. A fine "twiddle" would be the more likely response. A palmar slide would seldom be used to remove the top of a pen. These classifications could, however, be useful for more precise analysis of hand-function during assessment and treatment.

Release

The ability to release objects develops later than grasping. It begins to appear as the other hand grasps a second cube. Transfer begins by the other hand pulling the cube from the hand holding it; or the table top or mouth may be used as a halfway station. By twenty eight weeks the grasp of one hand and release of the other hand is simultaneous and the cube is easily transferred from one hand to the other. By thirty two weeks there is inhibition of this simultaneous grasp and release pattern. The infant will pick up and hold a first and then a second cube, but is unable to drop one of the cubes to pick up a third. At thirty six weeks the child is able to drop the cube voluntarily.

By forty weeks he can put the object down and then remove his hand from it. More and more in the following months the child becomes able to release more precisely and with better timing. At forty four weeks he still cannot release in a container, but by fifty two weeks he releases a cube into a cup. At this stage, however, when attempting to put a cube on top of another cube he pushes too hard or releases too soon. He is also not yet able to release a small pellet inside a bottle neck. By fifteen months he can accomplish both these tasks. By eighteen months he can release a cube on top of a two or three cube tower that he has built without knocking the tower down, but he can only build a tower of thirteen to fourteen cubes by three years, so improvement is gradual and steady.

A fifteen month old child cannot yet throw a ball when standing. He has to sit to throw it, but by eighteen months this is possible from standing (Gesell and Amatruda, 1974).

Horton (1971) confirms that the function of the muscles involved in release continues to develop as the child becomes older. Release is still difficult when throwing a ball at six years of age.

1.4. Development of components of movement related to hand-function

Irwin-Carruthers (1982) suggests grouping the functions of the upper limb under two headings:-

1) Manipulative (including sensory functions and emotional expression) and
2) Weightbearing (including protective responses)

This compares to Napier's classification (1956) into prehensile and non-prehensile function of the hand. Irwin-Carruthers underlines the importance of developing weightbearing in order to prepare the limbs for manipulative functions. This sequence is seen throughout the development of the upper limb.

The components of movements established at the shoulder girdle and gleno-humeral joint are the key to the development of weightbearing and manipulation. Initially movement of the scapula and gleno-humeral joint are linked. The baby cannot move one independently of the other. The ability to dissociate the movement of the scapula from movement of the humerus develops as control of the various components of movement at the shoulder is gained (Irwin-Carruthers, 1982). Movement at the shoulder is complex. Caillet (1981) in his detailed functional description of the shoulder girdle described seven joints - the gleno-humeral, suprahumeral, acromioclavicular, scapulocostal, sternoclavicular, costosternal and costovertebral. He explained that all seven joints have a part in placing the hand in a position for function. The scapula mainly provides stability, whereas the humerus provides mobility (Blacha, 1983a).

However, because of the emphasis on mobility in the shoulder girdle a large amount of stability is sacrificed (Mac Conaill and Basmajian, 1969).

The scapula glides on the thoracic wall where the trapezius and serratus anterior are mainly responsible for its movement and also for its attachment to the spine and thorax. Even the ligamentous attachment of the clavicle attaching to the sternum allows a great deal of freedom of movement (Caillet, 1981).

The clavicle is only present in animals that use their forelimbs for grasping and climbing and in man. It is not seen in animals that use their front limbs for standing. Amongst the specific functions of the clavicle are:-

1) holding the scapula and humerus away from the body to allow more freedom of movement and
2) allowing increased range of movement at the glenohumeral joint (Kent 1971). "Scapulo humeral rhythm" (a term first coined by Codman) refers to the interplay between the various shoulder joints to allow co-ordinated shoulder movement. For every two degrees of glenohumeral movement there is one degree of scapulothoracic movement. Total scapular movement is sixty degrees and total glenohumeral movement is one hundred and twenty degrees. If no movement is possible at the scapula passive movement can therefore be one hundred and twenty degrees. Active movement can, however, only be ninety degrees because of the lack of mechanical advantage of the deltoid, if the scapula does not maintain its normal relationship with the humerus.

The shoulder can only abduct sixty degrees when the humerus is held in inward rotation (Kent, 1971). To allow full abduction the humerus needs to rotate externally for about ninety degrees to allow the greater tuberosity of the humerus to move under the anterior edge of the acromion (Peat, 1977).

Peat points out that the glenoid cavity in the resting position points almost as much forward as laterally. Flexion/extension as well as adduction/abduction at the shoulder are therefore not in a sagittal or coronal plane to the body but on a diagonal plane. This needs to be remembered in treatment.

During protraction of the scapula the inferior angle moves faster than any other part. This allows the glenoid cavity to face upwards, thus bringing the upper limb into the position to do tasks in front of the body, and at or close to eyelevel (Mac Conaill and Basmajian, 1969).

The elbow is a synovial hinge joint and can extend fully to allow weightbearing on an extended arm. It also enables the position and movement of the hand to be graded quite specifically. In addition positioning and movement during different grasps, manipulation and "visual exploration", of the hand or its contents become possible due to pronation and supination accomplished at the various joints of the radius and ulna.

The wrist provides stability and mobility (Blacha, 1983a) The radiocarpal and radio-ulnar joints allow flexion/extension at an angle - towards the radial side for extension and towards the ulnar side for flexion. Ulnar and radial deviation is more limited. Although most of the movement takes place at the radiocarpal joint some movement also occurs at the intercarpal joint between the proximal and distal carpal bones. The ligaments of the wrist, as well as the muscles crossing the wrist, allow for stability as well as mobility as needed (Cailliet, 1981). Because of this the wrist facilitates grasp by allowing the hand to be placed exactly and it enables a strong grasp due to its stability (Blacha, 1983b).

When the wrist is flexed the efficiency of the finger flexors is only twenty five percent of what it is when the wrist is extended. The position of most efficiency is with the wrist in forty to forty-five degrees extension and fifteen degrees of ulnar deviation (Kapandji, 1970).

The hand can be used for gripping where strength may be important as well as for fine manipulation with dexterity. The sensory ability of the hand, especially of the finger tips, is important for all hand-function (Blacha, 1983b).

Bly points out that every movement involves a weightshift. In understanding movement and development of movement patterns it is, therefore, important to look at and understand directions of movement and results of weightshifting. Weightshifting also provides the stimulus for righting reactions. Righting reactions are the automatic background for all our movements and also the basis for equilibrium reactions (Bly, 1981).

Blacha explains that random movements result in weightshift which initiates movement causing elongation on the weightbearing side with lateral flexion on the other. She sees the progression as follows:-

1) Weightshift which is first seen in anterior/posterior movement will result, for example, in head-righting.
2) Movement of the body over a weightbearing limb will improve stability of that limb and elicit lateral righting reactions.
3) Once stability is achieved the limb can be moved over the body. This gives further kinesthetic input and increased stability.
4) With more stability of the trunk the upper part of the body can be moved against the lower part with the development of body on body righting reactions leading to axial rotation.
5) When the upper part of the body can be stabilized the body on body righting reactions make possible movement of the lower part against a stable upper part of the body.
6) This is followed by both parts being able to be counter rotated against the middle.
7) This leads to dynamic equilibrium with proximal control which enables refined distal control to develop (Blacha, 1983b).

The normal development of the components of movement of the upper limb have been analysed in detail by Bly (1981), Mohr (1981), Blacha (1983) and others. Relevant aspects of these will be discussed together with abnormal development of movement in the following section.

2. Abnormal Development

The child with cerebral palsy has a disorder in building up a "patterned structure of movement" (Milani Comparetti, 1967, p626). Bobath and Bobath (1964, p3) quote Hughlings Jackson as saying that "Nervous centres represent movements, not muscles. From negative lesions of motor centres there is not paralysis of muscles, but loss of movements".

Bly (1981) points out that abnormal development starts out parallel to normal development. However, in abnormal development many normal components are absent. The developing child therefore needs to learn how to compensate. These compensations are usually in the form of prolonged primitive movements which become pathological if they are not modified by the development of more advanced patterns of movement.

2.1. Primitive and pathological patterns of movement

Bobath and Bobath (1975) define primitive patterns as those that are present in the normal child at birth and up to three or four months. Abnormal motor patterns are not seen at any stage of normal development.

Whereas primitive patterns are seen with younger and less severely involved children abnormal patterns are more prevalent with the more severely involved and older children. An example of an abnormal motor pattern will be for instance when grasp is only possible with a flexed pronated arm and flexion of the head and trunk (Bobath and Bobath, 1975).

Primitive movement patterns are abnormal if:-

1) they are found with a variety of movement patterns belonging to different stages of development, (this means that some movement patterns appropriate to later stages of development have already been achieved while earlier patterns are still missing);
2) they are stereotyped and limited.(Milani Comparetti, 1981,) points out that whereas normal persons can choose to do any movement in the range of normality, the choice is limited in the

abnormal);

3) they are combined with abnormal postural tone.

2.2. Blocks to normal development

Bly (1981) described "milestones" in abnormal development identified by Dr. Elspeth Köng and Mary Quinton. These milestones are actually "blocks" to normal development. They prevent normal development. The baby, in an effort to achieve goals through his movements, compensates for these blocks as best he can, and in this way motor development follows an abnormal course.

Since axial extension is the first antigravity component to develop in the normal child, the first problem is the quality of extensor muscle activity. Antigravity flexion which normally develops a few months later may not develop at all, or not develop sufficiently, to counterbalance the extension. The baby is therefore "left with an abnormal quality of muscle tone and an abnormal quality of movement" (Bly, 1981, p124). At this stage muscle tone is usually low even in children whose extensor muscles are "strong". Because of this low tone, or the imbalance of antigravity flexion and extension, the baby cannot stabilize one part of his body while another part moves as the normal baby does. The child therefore learns to fix a part of his body abnormally. Although this helps him to accomplish a task, it prevents the development of both mobility and stability in that part. As he "fixes" more in this abnormal way he develops "blocks" which prevent the normal process of development. She describes "blocks" in the neck, shoulder girdle, pelvis and hips.

Neck block

Because such a child does not develop the head and neck flexion needed to balance head and neck hyperextension, the baby is not able to bring his head to the midline. He does not tuck in his chin in supine or in prone. The head is therefore always hyperextended and head control is poor. The baby compensates by elevating his shoulders to stabilize his head. This in turn blocks normal mobility of the scapulae which influences the development and use of the upper extremities. This posture is seen especially in sitting. Amongst other factors this neck hyperextension also leads to a decrease in mobility of the head, as well as less visual scanning of the environment, less eye hand co-ordination, and consequently poor manipulation abilities.

A neck block may also lead to asymmetry. Because he is not able to bring his head into midline (due to poor or absent symmetrical head flexion) he is more likely to be dominated by the Asymmetrical Tonic Neck Reflex (ATNR). He can only use one arm at a time for swiping or reaching. His eye movements are only used laterally and he misses the experience of convergence.

Blacha (1980,p. 2) says that asymmetry tends to lead to an "increase in extensor posturing". Because he does not have a midline orientation the child will have difficulty in using his hands bilaterally. Tactile and proprioceptive input will be unequal and lead to poor bilateral integration of the two sides and poor body schema. Bilateral exploration of his body will suffer. He will not be able to monitor play visually in the midline and may have difficulty in ocular convergence and eyetracking.

If asymmetry is prolonged due to the ATNR there will be retraction of the shoulder girdle and pelvis and shortening on the skull side. This will prevent the hands from coming to midline and righting and equilibrium reactions will be limited due to insufficient dissociation of body parts. Asymmetry will also affect the ability to bear weight on, and to shift weight to, the shortened side since elongation of the weightbearing side is not possible.

Shoulder blocks

In the normal child it is the development of dynamic stability of the scapulae on the trunk which makes forearm weightbearing possible without winging of the scapulae. Stability of the scapula also allows dissociated movements of the humerus, and subsequent shoulder control, to develop.

Stability of the scapula does not develop in the abnormal child. Forearm weightbearing may therefore not be possible, or only with poor quality, (that is with scapular winging) (Bly, 1981).

Blacha (1983a) looks at the upper limb in more detail. She describes the Scapula Adduction Block. Because of physiological flexion in the newborn the scapula is normally elevated and tipped forward. This forces the humerus into internal rotation and adduction as a result of the relationship of the humeral head to the glenoid fossa. In the normal baby the scapula is used in a relative state of adduction to reinforce spinal extension in all positions. With improved trunk control and development of the upper limb, the scapula becomes freed from reinforcing spinal extension and can be used in combination with the humerus in the development of normal prehension skills. The scapula therefore depresses, abducts and moves around the trunk to allow the humerus to move into external rotation or neutral rotation with flexion and relative adduction to allow distal function.

In the child with central nervous system damage the original adduction of the scapula is overused and to this is added increased scapula elevation. This produces more internal rotation, adduction extension of the humerus, and causes shortening of the scapula-humeral muscles which prevents the arm from moving forward in the normal way.

The child who is not severely involved will still try and bring his arms forward by using abnormal shoulder abduction/extension. The scapula and humerus are therefore forced to move as a unit so the scapula tends to be elevated, tipped slightly forward and excessively abducted, so it wings off the trunk overstretching Serratus Anterior which is normally used to stabilise the scapula on the trunk.

The second shoulder block Blacha describes is the Scapulo-Humeral block. In the normal baby of three months sufficient balance of flexion and extension in the neck and trunk makes dissociation of the scapula and humerus possible. This allows the arms to move forward and away from the body to prop the body in prone, and the infant can reach forward to regard his hands in supine. The humerus therefore changes from internal rotation adduction to more external rotation, abduction and this allows some interplay between pronation and supination. If this does not occur, weightbearing on the radial side is prolonged leading to ulnar deviation, pronation and wrist and elbow flexion. Neck hyperextension as a result of insufficient postural flexion will mean that "propping" can only be done with shoulder elevation which will prevent normal development of weight shift, balance, protective extension and reaching.

Whereas pronation and elbow flexion is normal in the first few months of life, by four to six months during prone weightbearing, extension of the elbow and supination of the forearm is developed. Because of poor or limited prone weightbearing, pronation and relative elbow flexion tend to be retained.

In the normal neonate wrist extension can be done passively, but becomes active only around four to six months as weightbearing on the extended arm takes place. Wrist extension against gravity is only seen around six to seven months. At the beginning grasp and release are "initiated by a tenodesis wrist action" (Blacha, 1983a, p.21). Flexing the wrist helps to open the hand and extending the wrist helps to close the hand.

Because of abnormal extended arm weightbearing, the wrist extensors are never fully extended. Flexion of the wrist is thus overused and the tenodesis action tends to remain and to limit finger mobility.

The tendencey to elbow flexion pronation, flexion of the wrist and weightbearing through the radial border of the hand lead to a tendency of fisting.

Crawling and pivoting in the normal child provides elongation of the finger flexors and tactile and kinesthetic preparation for the fingers. Weight transference occurs from the heel of the hand to the finger tips and from either the radial or ulnar border of the hand. Hyperextension in the metacarpophalangeal (m.p.) joints helps to achieve more distal extension while abduction helps to develop finger extension in grasp and release. This is still seen in the normal toddler.

Because of decreased and abnormal weightbearing the above finger patterns may persist. Lack of wrist extension may also be compensated for by m.p. hyperextension and interphalangeal (i.p.) flexion.

In the neonate the thumb is in the palm. The development of the cortex, weightbearing and equilibrium reactions, bring the thumb out of the palm. Initially the thumb is used with i.p. extension against the lateral border of the index finger. This gradually develops into true opposition.

Because of lack of weightbearing over the carpo-metacarpal (cmc) joint of the first digit the thumb does not move away from the palm (as it does with the normal child at six months) and the child does not achieve opposition (as the normal child does by nine to ten months). To compensate, the m.p. joint is hyperextended which decreases its stability and shortens the webspace. There is no finger tip pinch (often only a lateral pinch to the second or third finger): no real mobility or stability of the thumb; and decreased sensory exploration and grasping by the thumb (Blacha, 1983a).

Pelvic-hip blocks

The pelvic-hip blocks result in poor "trunk/pelvic control". The baby therefore does not practise lateral weight shifting and this interferes with the development of the normal righting reactions (Bly, 1981, p 130).

The child may not achieve independence in sitting due to limited interplay of anterior/posterior pelvic movements; and equilibrium reactions will be affected. He may therefore flex his trunk to maintain sitting and this may influence his ability to reach and to develop protective extension (Blacha, 1980). The child's inability to transfer weight will prevent development of rotation of the upper part of the body over the lower part; and the ability to cross the midline of the body with the upper limb will also be influenced (Blacha, 1980).

2.3. Abnormal sensory development

Blacha points out that normal motor development allows the child to explore his body and the environment which facilitates the processing and integration of sensory stimuli. When the motor ability of the child does not allow this (due to damage to the central nervous system) all sensory input including proprioception "may be limited, abnormal, inadequate, distorted and/or interfered with" (Blacha, 1980 p.1).

Parents of normal children rock their babies, talk to them, smile, and maintain eyecontact in close enough range to be seen clearly by the baby. As the normal baby shows he enjoys this, parents tend to continue with all types of sensory stimulation in their interaction with the baby. The normal baby can shut out redundant stimulation but it is doubtful whether the abnormal baby can do this (Blacha, 1981). The abnormal baby may be irritable, lethargic, or may have abnormal primitive reflexes. By his reactions his parents may understand that he does not want their interaction. Their sensory input to him will therefore be different and probably much less than for the normal child. On the other hand, because he is not able to shut out stimuli the sensory input may overload some children.

Harrison and Connolly (1971) said that proprioceptive feedback of the spastic person may be difficult to decipher so he cannot use this to judge whether a movement has been done successfully. When he attempts a movement many muscles may be unnecessarily involved so he does not learn the 'feeling' of correct movement.

Tizard et al (1954) found the following in their sensory testing of children with hemiplegia. Fifty percent of the children had sensory disturbance on the affected side. The children who were born with cerebral palsy had astereognosis and problems with two-point discrimination but primary sensation was intact. Position sense, touch, pain and temperature were also affected in children with acquired hemiplegia.

Bobath and Bobath (1975) found that even if spasticity was slight the use of the hand would be minimal if tactile discrimination and stereognosis were poor. Bobath (1980) believes that astereognosis and poor proprioception are not necessarily due to brain damage but may be because of lack of 'normal' experience of sensation.

2.4. Abnormal development of specific types of cerebral palsied children

Bobath and Bobath (1975) have described the abnormal development in the various types of Cerebral Palsy.

Diplegia

The development especially of the upper limbs in diplegia is seen as follows:-
The physiological flexion seen at birth may remain for many months. Head control develops although later than normal. The child can get his hands together in midline and to his mouth; and he develops midline orientation of his head. When able to lift his head in prone to get onto his forearms he starts pulling himself along on flexed arms used symmetrically. He cannot use them reciprocally due to lack of rotation of the shoulder girdle and pelvis.

Sideways and backwards support on arms in sitting develop late or not at all due to forward flexion of the spine and shoulder girdle in sitting. Balance in sitting without arm support remains poor and therefore forces the child to support himself with one arm while playing with the other (Bobath and Bobath, 1975). Reaching upwards while looking up is impossible because of insufficient balance, even if only one arm is used to reach up while the other is used for support. In addition, upper limb function is limited by the inability to weight shift and rotate the trunk. Lack of mobility of the trunk prevents weight shift on the upper limbs and this blocks pivoting movement. Development of dissociation between the arms is therefore prevented. Insufficient practice due to instability also prevents the development of hand skills.

Because of limited rotation the child does not use lateral space and especially not the space behind him. He tends to use only the lower space in front of him, pulling things into this area.

The head-neck retraction in the diplegic hampers the development of visual attention, scanning of the environment and the following of moving objects (Rast, 1984b).

Jensen and Alderman (1963) looked at typical abnormal hand postures in cerebral palsied children. The effort of picking up a pellet caused diplegic children to revert to more primitive or immature hand postures. The most typical hand posture noted in these children was hyperabduction of the fingers before grasping.

Hemiplegia

In the hemiplegic baby the upper limb may remain retracted and flexed or may extend stiffly by his side if his head is turned towards it. He may not be able to bring his hands together above his chest nor put his affected hand to his mouth. He does not reach out with that hand. It may be 'fisted' more often than the other hand, but may be open at times. At the beginning his posture may be symmetrical until he uses his unaffected hand functionally, and tends to look more that way.

He will be late in sitting up. When he does he likes sidesitting with his weight on his sound side. At this stage flexion and pronation of the affected arm with retraction of the shoulder and 'fisting' of the hand is seen more frequently and is reinforced by associated reactions (Bobath and Bobath, 1975).

Associated reactions differ from associated movements in that they are stereotyped. They are also one of the main factors leading to increase of spasticity (Bobath, 1971).

The hemiplegic child may focus more and more on the sound hand neglecting the affected hand. This hand may also have sensory deficits and the child may even completely reject the hand or dislike being touched on that side. The Moro reflex may persist longer on the affected side.

The child will miss the normal bilateral use of both hands together in midline and of transferring objects. Flexion of the upper limb is also accompanied by flexion of the neck and trunk towards the affected side. This pulls the shoulder girdle down and the pelvis up with resultant shortening of the whole of the affected side.

As he starts walking associated reactions reinforce the retraction of his affected upper limb. Because of lack of protective extension on this side he tends to orientate himself completely towards the normal side. Balance reactions towards the affected side therefore do not develop.

There is often a size discrepancy especially in the upper limb. This may be due to less proprioceptive input and weightbearing (Bobath, 1975). This growth disturbance is almost always accompanied by a major sensory deficit (Samilson, 1966, Tizard et al, 1954).

Where sufficient control is present there seems to be a "slowness of the act of grasping". This is seen in the initiation of reaching out in grasp or even just in getting the hand ready to grasp, as well as in flexion of the fingers around the object (Twitchell, 1958 , p.14). Twitchell also noted a lack of fixation of the wrist and lack of synergic action of the wrist extensors with grasp.

If untreated the flexor spasticity may become so strong in the arm that the child cannot open the hand any longer. When trying to use the hand he can only open the fingers with extreme flexion of the wrist. The hand may be pronated and deviated towards the ulnar side (Bobath and Bobath, 1975).

Mohr (1981) points out that there are various stages in the development of abnormality should no intervention occur, namely:-

- the original insult;
- compensation by the child to achieve function in spite of the insult;
- the compensatory patterns are repeated until they become a habit;
- contractures may start to develop if the habit, for example, reinforces flexion or extension without the opposite pattern;
- deformities result if contractures exist long enough.

Acquired hemiplegia

Mohr (1981) pointed out that a child who acquires hemiplegia after four or five years of age already has a good bony structure. Although the child will start off with low tone, his tone will increase as soon as he starts to move. This starts in the neck and shoulder region and continues to the lower back and pelvic region. He may start with adduction and elevation of the scapula which brings the humerus into extension. The elbow and wrist will mostly be flexed and the forearm pronated. The position of the arm depends on the actual lesion. Sensory deficits seen at the beginning usually change with treatment and time. Everything that will recover spontaneously recovers within the first eighteen months. Treatment however may still make a difference up to ten years after the insult. This does not mean continuous treatment. Treatment should be given while progress occurs and tapered off as plateaus occur, but should be commenced again as the need arises.

2.5. Abnormal development of visual abilities

Although the normal child of six years has less control of eye movements than the ten year old, cerebral palsied and other brain-injured children have less control than normal children. The child has to deal with "noisy channels". He is unable to fixate only on a specific target as he is continually getting information from other parts of the visual field. Both saccadic and pursuit movements are less regular and less precise (Abercrombie, 1970).

Instability between the neck flexors and extensors will also affect the control of eye movements (Rast, 1984b).

Miranda (1976) tested visual fixation of preterm and high risk infants in the early months of life using patterned targets found interesting by normal infants. He found that poor visual attention was more predictive of later neurological or intellectual impairment than neurological assessment at an early age.

3. Assessment

The three most important reasons for assessment of a child are:

- to determine whether the child needs intervention;
- to plan an exact programme of intervention;
- to reassess whether this programme has been effective and to plan accordingly.

Bobath (1971) emphasized that it is not only important to find out that the child cannot do something but to try to determine why he cannot do it. Mohr (1981) believes that an important part of assessment of a cerebral palsied child is the observation of what he can do and how he does it. Postural tone, changes of tone in different positions, postural and movement patterns, and functional abilities and disabilities are important to note during assessment (Bobath, 1969). Rast (1984b)includes some therapeutic handling in her assessment to determine how easily changes of abnormal patterns can be achieved.

Milani Comparetti (1981) says that by asking whether a child is normal we ask a question about his present and future. The answer should be diagnostic as well as prognostic. Thus the aim should not be to assess a status, but to reveal signs of the developmental process.

In assessment it is also important to discover, for instance in an apathetic child, where there would be a "spark of interest" or a "bit of skill" or a "crumb of success". These would be used to lead the child on a course of treatment that might eventually become self rewarding for him (White, 1971,p.274).

3.1. Assessment of aspects related to hand-function

Although all agree that quality of movement is the most important element to assess in the cerebral palsied child attempts have been made to find efficient ways of assessing related aspects. The following are examples:-

Muscle tone has been assessed by moving the person in normal postural patterns (Bobath, 1967, Trombly and Scott, 1977) assessing the resistance of a body part to passive stretch (Trombly and Scott, 1977) and observing tone at rest and during activity (De Gangi et al, 1983). Rast (1984b)also feels and observes tone after effort - for example, in jumping.

The automatic postural reactions used to achieve and maintain head control, the normal alignment of the head, body and limbs and to regain balance, for example righting and equilibrium reactions, are underlying to all voluntary movements (Bobath, 1969) and therefore need to be assessed.

Rast (1984b) assessed associated reactions by the use of appropriate activities done with the sound hand of a hemiplegic. She tried to describe exactly what happens in the affected limb and also noted how easily the associated reactions could be overcome by the child.

Stewart Lord (1973) assessed the posture of the affected hand of hemiplegic children at rest and during writing on a blackboard with the unaffected hand.

Zancoli and Zancoli (1981) classified the spastic hand according to movement and posture at the wrist and fingers. Others classified the hand according to the position of the thumb (Stewart Lord, 1973, and House et al, 1981).

Hohlstein (1982) stressed the importance of assessment of joint stability in the hand. Most therapists assess stability and mobility of joints together with assessment of tone (Mohr, 1981). Stewart Lord found it important to assess the stability of the metacarpophalangeal joint of the thumb in extension and with the thumb in abduction. Both were compared to the unaffected hand of the child.

For proprioception Laszio and Bairstow (1980) designed methods to measure 1) the accuracy of discrimination of limb movement and position; 2) the accuracy of positional matching of the two upper limbs and 3) the accuracy of memory for complex movement patterns.

Blacha advised looking at motor patterns to note whether they are primitive or pathological; whether components are primary or compensatory; and to note the effectiveness of automatic as well as voluntary patterns of movement. This is also considered in the analysis of functional skills (Blacha, 1983b).

Blacha analysed three methods used by normal children to take off a 'T' shirt. She described the components of movement of the head, trunk, shoulders, elbows, forearms, wrists and hands. This type of analysis can help to assess the performance of a child with cerebral palsy in order to identify specific components that the child is unable to execute in the normal way.

Wilson et al (1984) designed a functional test for adults with hemiplegia. The test assessed representative functional tasks at seven levels of function. This proved useful to assess the patient's level of performance. The test, however, does not discriminate between the reasons that would make certain tasks difficult or impossible for each patient.

3.2. Specific assessments of hand-function

Over the years hand-function assessments for adults have been designed to assess such functions as type of grasp (Carroll, 1965, Jacobson-Sollerman and Sperling, 1977); function and timing (Smith, 1973); and handstrength and dexterity (Kellor et al, 1971).

Kamakura et al (1980) classified static grasp of the adult into fourteen patterns under four categories, namely, - power grip, intermediate grip, adduction grip (excluding thumb involvement) and precision grip. They attempted to define these very precisely by using ink containing glue on each object so that contact areas of the fingers on the object would be clearly seen and involvement of each finger could be identified exactly.

Hand-function tests for children have included assessment of dexterity (Annett, 1970), grasp and pinch strength (Ager et al, 1984) and analysis of hand-function during activity (Sherik et al, 1971, Weiss and Flatt, 1971).

The assessment by Sherik and colleagues was designed to assess children with "congenitally anomalous" hands. Various types of pinch and grasp are analysed, scored and variations from the normal are carefully described. The child is requested to pick up certain objects and is then also observed during play. A child may be able to perform a specific movement on request and yet use a more primitive grasp during more spontaneous movement. These authors included active and passive range of movement and measurements of pinch strength and hand size.

Although this type of test could possibly be used as part of the assessment of hand-function of cerebral palsied children - no consideration is given to the rest of the upper limb or to reach, manipulation or release.

Ammon and Etzel (1977) presented a developmental model including hand reflexes, visual response, reaching, grasp and release as well as emerging behaviours like hitting, shaking, manipulation, dropping, throwing, transferring and handling of more than one object. They stated, however, that it should not be seen as an assessment instrument. It had not been tested for inter-rater reliability or for item validity.

The assessment of Cliff (1979) includes posture, regard, approach, grasp, manipulation and release. Expected behaviours in all of these areas are presented up to 52 weeks. Each behaviour is described developmentally to facilitate qualitative judgement. The child is assessed supine or sitting (depending on the age of the child), mostly while involved in free play with the mother. This appears to be an excellent assessment of hand-function but is not detailed enough to assess progress over a short period of treatment in older children. In addition validity or reliability is not mentioned in the description of the assessment.

The Erhardt Developmental Prehension Assessment (EDPA) (See appendix A) has been designed particularly for children with Developmental Delay and Cerebral Palsy. The norms are based mainly on the work of Gesell, Halverson, Perlmutter and Frantzen. Eventually nine sources of assessment were used and items at a certain age level were only chosen when there was 50% or more agreement that this occurred at that specific age level. Test behaviours were chosen that occurred at four week intervals from birth to fifteen months. Erhardt argues that the essential components of hand-function are laid down by this time. Thereafter only refinement occurs. Although this assessment has been used extensively by the author and others it has not been standardized.

Interrater reliability was done by 16 raters in two groups of 8 raters each. They were all qualified occupational therapists with paediatric experience of three months to ten years. They had no experience of using the EDPA. Each group rated two videos of the assessment of one child each. The four children were between two and ten years with diagnoses of various types of cerebral palsy. All 100 items of the test were covered although not all with each child. Each video was taken while the author assessed the child. The raters were requested to score the results.

Of the 306 judgements all raters agreed with the author 142 times, seven agreed with 44 additional items, and six with thirty eight additional observations. Therefore six or more raters agreed with 73% of the judgements.

Correlations between raters for the items of each specific child ranged from ,418 to ,853 and all were significant at the ,001 level. This assessment was therefore considered capable of yielding repeatable results.

Test-retest reliability studies have not yet been done to determine the consistency of the EDPA. Erhardt defended the validity of the test by answering a checklist of questions by Berk and De Gangi compiled to assess the usefulness of a motor scale, as follows:-

1) The EDPA attempts to include nearly all prehension behaviours within its defined parameters and the items provided are therefore a representative sample.
2) The EDPA is based on a sound theoretical foundation with illustrations and detailed descriptions defining each pattern component. Nevertheless, studies are needed to provide statistical evidence of construct validity.
3) All behaviours included in the EDPA are measured directly by observation of the child's responses.

4) Informal feedback reports agree that the EDPA is "extremely appropriate" for children with developmental delays or dysfunction. Studies to determine the validity of the test to discriminate between factors contributory to hand-function still need to be done.

The EDPA is very comprehensive and therefore very time consuming to administer. The scoring criteria are useful. Behaviours are described in detail but sometimes include several factors. A score of "Incomplete performance" can therefore vary depending on the number of factors involved for a specific child. However, when the specific behaviours seen are marked on the form, these descriptions can aid in qualitative assessment. The EDPA is developmental in approach and at times quality of posture and movement is not considered to a sufficient degree.

Note is taken of posture, weightbearing and the position of various parts of the upper limb when arms are at rest or during reaching. However, only the hand and wrist is considered when observing grasp, manipulation and release. The position and movement of the trunk and rest of the upper limb during these activities can have important treatment implications.

To a certain extent the section of, for example, "The Arms on Approach" and "Grasp of the Dowel" both in sitting can be combined but will need some adjustment to give the information required.

The performance of a child is not always consistent in grasp, manipulation and release. It may vary depending on the way it is requested by the examiner, the number of trials allowed and many other contributing factors.

Instructions on how the assessment should be presented were not specific and results could vary depending on the interpretation of each therapist. A video cassette on the administration of the EDPA has just been released in the USA, but this has been too late to be used in this study.

3.3. Assessment to determine the effectiveness of treatment

Few studies have been done to show the effectiveness of neurodevelopmental treatment methods. De Gangi, Hurley and Linschied (1983) assessed, amongst other factors, postural tone, weightshift and weight-bearing in a position with which the specific child was having difficulty. The four children in their study were assessed in eight sessions, each over a period of five weeks before and after treatment sessions and before and after play sessions by a person untrained in any therapy. This person used nonspecific movement and touch in play. The sequence of the play and treatment sessions were alternated each time. All sessions lasted twenty five minutes. They found no difference between the effects of single sessions of treatment and play.

The testers, however, were not skilled in child development or in neurodevelopmental treatment. They were just trained to administer the specific tests. Although the interobserver agreement was high, it is possible that a person without the necessary background may not be aware of the fine differences that may mean more or less improvement in each child. To administer some of the "activities" used to test each child, the child had to be handled by different people and this is not always acceptable to a child of between ten and twenty two months. Without neurodevelopmental knowledge one's handling of the child may also affect the child's motor performance. During spontaneous activity, at the assessment, effort may have affected the tone of the child and this may have confused the picture of the child after treatment.

The authors acknowledge that the time span was very short and that their measures may not have been sensitive enough for the improvement which may have occurred. However, this does point to the difficulty of assessing progress in the cerebral palsied child.

Scherzer et al (1976) showed more improvement in children under 18 months treated with neurodevelopmental treatment methods to stimulate motor milestones. This was, however, compared to passive range of motion exercises. In addition the parents of the experimental group were encouraged to carry over treatment principles at home, whereas the parents of the control group were asked to refrain from intervention at home. More improvement in the experimental group was seen in motor status, social maturation and home management. The least difference was seen in home management.

Harris (1981) set four specific treatment objectives for each of the Down's syndrome children in her experimental study to determine the effectiveness of neurodevelopmental treatment. A significant difference in improvement was seen in favour of the experimental group in the treatment objectives. However, the control group received no treatment in lieu of the forty minute sessions three times per week for nine weeks, received by the experimental group.

More experimental studies are therefore needed to assess in a more controlled way the effectiveness of different aspects of neurodevelopmental treatment.

4. Treatment

Smith (1983, p2) considers treatment of a child with cerebral palsy to be a "synthesis of physical handling to facilitate appropriate postural responses on an automatic level and of goal-directed activity to develop skill mastery on a voluntary level".

When treatment is aimed at improving function of the hand, functional activity must necessarily be a crucial part of the therapy.

4.1. The use of activity in treatment

Cynkin (1979, p13) says that when man is involved in activity "the eyes become keener, the hands surer, the muscles stronger, the endurance greater, the mind sharper.....the perceptions finer, and the feelings more orderly". Individuals have a tendencey to desire change in a direction from dysfunction to function. Activity, however, will only enable this kind of change to take place when it has relevance and meaning to the specific individual (Cynkin, 1979). The contribution of the activity towards development, learning and remediation as well as motivation for the activity depends on the choice and application of the activity for a specific individual. An activity needs to be matched with the individual's readiness to learn or to receive stimuli, and with his or her socio-cultural values, norms, and personal characteristics..." (Fidler, 1981, p570).

Functional activity

Williamson (1982) states that involvement in functional skills required for daily living and in play is the means by which motor control is achieved in normal development.

Mohr (1981), however, pointed out that functional activities do not just happen after general treatment of the cerebral palsied child. Neither can they happen through practice if the child cannot accomplish them using the "right" patterns of movement. One may, therefore, need to work on elements of movement and then put them together in functional activities like dressing (Mohr, 1981). Milani Comparetti (1981) stresses that in treatment the aim should be to translate the movement experience the child needs into real life experience for the child. Rast encourages the child to use a correct movement pattern in function immediately after it has been achieved. This could be even a simple part of a functional activity.

When movement is learned engrams are formed. To form an engram a movement needs to be done millions of times. This can only be done if treatment culminates in functional activity. "Successful performance is a reward in itself and encourages further attempts at successful performance" (Kotike, 1980, p 572). Training to the level that the activity is functional in daily life becomes a rewarding and self-perpetuating activity. In training of co-ordination, success is therefore the keynote.

When movement is performed incorrectly, incorrect engrams are formed and this delays the development of correct engrams. Is is therefore important to ensure that incorrect movement is discouraged during treatment. An activity needs to be broken down into units of sufficient simplicity for the person to handle correctly at his level of co-ordination. If he already has correct engrams, new engrams can be combined with these.

Blacha (1983b) suggests breaking up functional activity for the cerebral palsied child. She prepares the child to take over components of the task as he becomes able before confronting him with the whole task of, for example, putting on socks. Such a task has many components that need to be learned. If they are taught simultaneously they will produce excess effort, overflow and poor patterns of movement. If the child is given the preparation and assistance he needs initially (by inhibition and facilitation) this assistance can gradually be withdrawn. The child can also develop expertise in each component before they are combined in tasks. In this way he can perform these tasks without abnormal movements. Rast (1984b) believes that each simple function the child learns initially should eventually become part of a more complex function.

Harrison (1975) suggests that as a movement sequence is learned, units of movement are formed that can be completed without cognitive effort. With practice more is incorporated into each unit. The units become longer so fewer units are ultimately needed to complete a movement sequence. The movement, therefore, becomes smoother and faster since less time is needed for the transition of one unit to the next (Harrison, 1975). Inhibition of unnecessary movement also improves (Kottke et al, 1978).

It is, however, not necessary to teach a child separately every variation of ability at each stage of development. The goal of the therapist should be to facilitate the basic motor patterns so that the child can build many skills around these (Bobath, 1967). It is important to allow the child to do what he can but to help to find the most therapeutic methods of doing this (Rast, 1984b).

Means or end

Kottke (1980) believes that voluntary muscular control can increase the effectiveness of therapeutic training since the voluntary contraction of a muscle under direct consciousness forms the basis for the development of an engram or automatic pattern.

Trombly and Scott (1977), however, point out that when attention is directed to the end goal, less cortical control is required than when directed towards the movement itself. When movement has become automatic, subcortical control is involved.

Luria (1963) considers the plasticity of mental activity as being one of its most important and characteristic features. He quotes Bernshtein who showed that a specific action, like driving in a nail, is hardly ever carried out by the same system of muscles (except when it is highly automatic). If the position of the body is changed slightly the activity will be done using a completely different selection of co-ordinated acts but preserving its final aim. Sometimes the same effect can be achieved by altogether different means.

This was illustrated by Bernshtein, as quoted by Luria, where the same characteristics of handwriting are preserved whether a word is written with the left or right hand or with any of several other parts of the body.

Luria quotes Leontev and his co-workers who asked wounded persons
1) to raise the affected hand as high as possible
2) to touch a certain point and
3) to grasp an object suspended high.

These patients were able to lift their arm on average 13^{o} more on task 2 and 18^{o} more on task 3. They concluded that the performance can be improved when the goal of the task is changed to the purpose rather than to achievement of the movement. Mountford (1971) underlines the premise that when the attention of the individual is directed away from himself to a functional goal this promotes better functional integration. In focusing attention on the task at hand the automatic character of the nervous system can be implemented optimally.

Kirchner (1984) compared a purposeful activity, rope-jumping, to an exercise of jumping using the same muscles and exertion with the same individuals. She found that the purpose in the first activity allowed participants to continue longer and put in more effort without being aware of extra effort or time.

The adaptive response

Ayres (1972, p125 - 129) coined the term "adaptive response" to explain the need for an activity to be designed to elicit the exact response needed to help the individual towards more integrated function.

King (1978, p432) discussed four specific characteristics of the adaptive process in the individual as follows:-

1) It can only be an active response of the individual. It "cannot be imposed, it must be actively created".
2) It is elicited by the "demands of the environment". In therapy the occupational therapist needs to structure the environment and especially the demands of the activity to evoke the specific response.
3) It is best organised subcortically. Sometimes it can only be organised below the cortex. Conscious attention to the task itself and not to the process allows the "subconscious centres" to "integrate and organise" a task response.

In occupational therapy the patient needs only to concentrate on task fulfilment (for him the primary goal) and this provides the motivation. The patient may or may not be made aware of the "secondary goal" of the adaptive response. This will depend on whether it will contribute to his motivation and co-operation in treatment.

4) It is self-reinforcing. As the first demand is met successfully, this provides a stimulus to attend to the next demand "at a higher level of challenge" (King, 1978, p 433).

Play - the child's most natural activity

"Play is volitional activity characterized by 'fun' and calculated to excite and to amuse the individual" (Takata, 1969, p314). Play is a "process not an entity" (p315). It helps to develop the child's unique potentials. Play is used to practise motor skills and later sociocultural attitudes and many other skills.

Florey (1981,p519) sees play as a "repetition of experience, exploration, experimentation and imitation of one's surroundings". Reilly (1974) agrees that exploration is an early form of play. Tizard and Harvey (1977,p71), however, see exploration as an "investigation of the properties of the environment" and not as play. Play, by their definition, is more making use of the environment for "self devised plans". They, however, mention that just as the adult has much enjoyment from work-play the child often enjoys goal-directed activities to achieve some extrinsic end. Children want to learn, and as they learn more they want to learn more. Play is the natural way for the child to learn. Young children playing combine a "seriousness of purpose with an enjoyment" (Marzollo and Lloyd, 1974, p3).

Rast (1984b) adds to her definition of play the element of free choice, which she feels is necessarily forfeited in treatment. Play used in treatment is therefore in her definition more work than play, but can still be fun for the child.

Piaget and Inhelder describe four types of play:-

- Exercise play - begins at the sensorimotor stage in infancy and continues thereafter. When the child has discovered a movement he continues this for the pleasure of the movement or for the effect of the movement or to practise a new skill.
- Symbolic play - develops between two and three years up to five or six years. Through symbolic play he assimilates reality for himself whereas in most other aspects of his life he has to accommodate to the external world. A little girl might pretend to be a church with the bell ringing in the steeple, something which had impressed her earlier.
- Games with rules - are mostly transmitted from child to child and therefore are closely related to social interaction with others.
- Games of construction - also develop from symbolic play and continue into mechanical constructions which lead to solutions to problems and intelligent creations at a later stage (Piaget and Inhelder, 1979).

Knox devised a play scale which was for children (0-6 years) and was revised by Bledsoe and Shepherd (1981). This included space management, material management, imitation and participation with others with norms at yearly intervals. In the area of material management the development of manipulation, construction, interest, purpose and attention are particularly applicable to skills of hand-function. The 5 - 6 year old likes to replicate reality, can concentrate on a single theme for 10 - 15 minutes and is interested in making something useful. He likes small construction and can make a recognisable product. He uses tools to do this and can combine various types of material.

4.2. The role of feedback in treatment

Cerebral palsied children have fewer patterns to choose from and the patterns are more stereotyped and less selective. This is due to problems with the inhibition of muscular activity not directly involved in a specific movement. When a hemiplegic tries to move his hand or foot, his whole affected side may become involved (Bobath and Bobath, 1957). One of the problems confronting cerebral palsied children is inadequate kinesthetic feedback (Connolly, 1968). So many contractions occur in one movement that the child may never learn to perceive feedback from muscles correctly (Triptree and Harrison, 1980).

In order to perform a complex skill a pattern of movement needs to be integrated in the correct temporal sequence. This cannot be done without being aware of the direction and extent of a previous movement. This is where the movement of the cerebral palsied child typically breaks down (Jones, 1974).

No system can operate independently of the other systems. There is continual feedback through different channels. The past acts as a foundation for the present and the feedback of the present is part of the foundation for the future. If a breakdown occurs in any part of the complex circuit a pattern of dysfunction is laid down and confuses the foundation for the future (Huss, 1981). The child can only use what he knows. If his experience of movement has only been abnormal he will use these abnormal patterns of movement for function and reinforce them (Bobath, 1967).

The child can only learn to do a movement as he learns the feeling of the movement done with normal effort (Bobath, 1969). Kottke and his coworkers (1978) also emphasize the importance of noneffortful activity for effective learning to take place. He stresses the importance of not allowing overflow which will confuse the feedback of the desired movement. Intervention, therefore, consists of trying to elicit a normal response at the level at which it can be performed so that a normal foundation is laid down (Huss, 1981).

It is important to keep in mind that the child gets feedback from every movement he performs (Blacha, 1983b). Therapists using neurodevelopmental therapy with children provide the children with continual sensory input. This includes proprioceptive, tactile, vestibular, visual and auditory feedback which is given simultaneously or independently. Some abnormally developing children may not be able to handle all this sensory input. The therapist therefore needs to be very much aware of the effect of her sensory input on the child. Input may have to be carefully graded so as not to overload the system. Time must be given for a specific sensory input to be experienced so as to allow more normal input to occur (Blacha, 1983b). If the child is hypersensitive to touch, touch pressure in these areas first by the child and then by the therapist may need to be included in treatment (Rast, 1984b).

In an attempt to reduce this confusing feedback a selective rhizotomy of only the abnormal posterior nerve rootlets between L2 and S1 has led to good results (Peacock and Arens, 1982). Spasticity was decreased with subsequent improved function not only in the local segments, but also in the segments supplied by the cord proximal to the section and by brainstem centres because of ascending collaterals. They concluded that this was due to the abnormal input being removed so clearer input was possible. There was a numbness during the first week or two after the operation but this soon disappeared and in the final result sensation was not reduced in any way.

Bairstow and Laszlo (1981) believe that where kinesthetic perception is deficient this needs to be worked on first. Specific tasks to improve kinesthetic awareness will be more productive than a programme of general movement training,

Pinelli (1981) postulates that the correction of the neurologically impaired system could be achieved by inhibition of afferent (proprioceptive) or efferent neurons. Drugs that "selectively reduce the activity of afferent neurons or enhance the activity of internuncial systems at the spinal or encephalic levels" (Pinelli,p359) have been used. He believes that what is needed for the spastic is "an induced contraction of the agonist muscles, triggered at the proper phase of the movement" with simultaneous inhibition of the antagonist muscles (Pinelli, p359). This, however, does not keep in mind that voluntary movement is only learned by the sensations supplied by active movement of the individual (Mac Keith in Bobath, 1980). If Pinelli's suggestions could be combined as a facilitatory method during an activity this could then gradually be withdrawn as the child is able to repeat the more normal patterns of movement while doing the activity. Results could possibly be achieved in this way with the more severely involved older cerebral palsied child.

Jones (1974) quoted various studies where, for example, active movement of the eyes or hand enhanced the perception of movement. He believes that present treatment is based on proprioceptive awareness. In his opinion corollary discharge has a bigger role to play and this can only be achieved by the child's active participation. He concluded that it may be more effective to teach the child to "monitor" his own movement by the use of vision.

Augmentation of kinesthetic feedback

Connolly (1968) believed that if feedback could be augmented until the child is able to distinguish the kinesthetic signal from the background "noise" the additional feedback could later be faded and shifted back to kinesthesia only by suitable training procedures.

Harrison (1975) gave five spastic individuals augmented feedback and they were able to learn to relax and perform high, low and intermediate level forearm flexion activity as well as sequential and simultaneous patterns of activity in the biceps and forearm flexors. Other studies using electromyographic auditory and visual signals reported success with cerebral palsied children (Talbot and Junkala, 1981); cerebral palsied adults (Neilson and McCauley, 1982); hemiplegic patients (Hurrell, 1980 and Triptree and Harrison, 1980); a retarded cerebral palsied adult (Asato et al, 1981) and varying other patients with neurological involvement (Brudny et al, 1974).

Greenberg and Fowler (1980) found that kinesthetic bio-feedback with an auditory and visual signal was just as effective as conventional occupational therapy treatment to increase range of active extension in the elbows of hemiplegic patients.

4.3. Basic requirements for treating hand-function

Blacha (1983a) considers the following to be essential when working on hand-function:-

- equal balance between neck flexors and extensors;
- trunk stability and mobility;
- pelvic mobility and stability;
- a stable base for movement;
- shoulder mobility with stability;
- elbow and forearm control;
- wrist and digital function;
- prehension.

Bly (1980) focuses in treatment on correction of the results of blocks to development. When the child, for example, has a neck block leading to hyperextension of the head, she starts working on elongation of the head and neck extensors while encouraging active involvement of head flexors. She will decrease shoulder elevation and work on mobility of the shoulder girdle before working on upper extremity use. She, however, emphasizes treatment of the whole child so all factors contributing to the child's problems need to be considered.

Trunk stability and mobility need to be worked on. Bly describes specific treatment to overcome both the anterior and posterior pelvic tilt pelvic hip blocks.

To achieve a stable base for movement of the upper limb (in addition to the above) the shoulder girdle needs to be considered first. Bly advises working on "scapular stability, scapulo-humeral mobility,.... active humeral dissociated movement ..... in addition to improving upper extremity weight bearing and weight shifting" to overcome the shoulder block (Bly, 1981, p129).

The development of hand-function does not only depend on motor control of the shoulder girdle, arms and hands. The development of vision, perception, perceptual motor ability, and cognition all influence hand-function (Levitt, 1977).

When concentrating on hand-function one has to keep in mind the many direct relationships between the development of gross motor function and that of hand-function. For example:-

- head control is important for eye-hand co-ordination.
- head, trunk and pelvic postural fixation in various positions allows for a stable base and is essential for hand-function.
- hands and arms are used to help to achieve various positions and for saving reactions when balance is disturbed. Levitt believes that the same arm synergies used, for example, for rolling are also used for voluntary reach. She, therefore, starts using these synergies in rolling and then brings them into hand-function (Levitt, 1977).

4.4. Basic treatment principles

Bobath and Bobath (1964) summarized the principles of treatment of the cerebral palsied child as follows:-

- normalization of tone ;
- working to establish the most automatic postural reactions; (This means working on righting and equilibrium reactions as well as on less automatic postural adjustments to variations in movement.)
- building on the above factors to develop more voluntary purposeful movement skills.

Normalization of tone

Tone should be high enough to resist gravity without excessive effort but low enough to allow smooth movement (Blacha, 1982). Normalization of tone is achieved by inhibition of abnormal patterns of posture and movement (Bobath, 1971) and by specific proprioceptive stimulation (Blacha, 1982).

Spasticity is "coordinated in definite synergic patterns". The patterns of spasticity have to be counteracted during treatment to create more normal tone that can form a basis for more normal coordination to be developed (Bobath, 1969, p.19).

By handling the child, muscle tone and abnormal postural patterns can be influenced and more normal patterns of movement can be facilitated (Bobath and Bobath, 1964). The therapist needs to be able to appreciate changes in muscle tone of the child and to be able to adjust her handling in order to continue to normalise tone optimally.

Spasticity can be reduced throughout the body by changing part of an abnormal postural pattern at a 'keypoint of control'. These keypoints are mainly proximal, for example, the neck, spine, shoulders and pelvic girdle. They are used by the therapist to help the child move in reflex inhibiting patterns that counteract abnormal postural patterns of movement. As soon as abnormal movement is inhibited more normal movement is facilitated or is requested of the child (Bobath, 1969).

Handling enables the therapist to assist the child to achieve a normal active automatic movement. It also gives the child proprioceptive cues of what he is required to do. Kottke and his colleagues (1978) mention that conscious monitoring of a movement by proprioception takes 500 milliseconds whereas to understand, perceive and respond to a verbal direction needs 2.5 seconds.

One of the reflex-inhibiting patterns that can be used to inhibit tone is rotation of the shoulder girdle on the pelvis. Facilitation of movement from one position to another also needs to be initiated and accompanied by rotation of the child's head or trunk (Bobath and Bobath, 1964). Using rotation in treatment also helps to integrate flexion and extension and helps to counteract patterns of fixing

(Hansford, 1984).

Weightbearing through the affected upper limb in a hemiplegic child can inhibit associated movement that would otherwise occur while the unaffected hand is used in activity. Weightbearing through various parts of the hand prepares the hand for each stage of hand-function. If this weightbearing does not occur, or occurs abnormally, the development of hand-function is influenced adversely. Correct weightbearing through the hand is therefore important in treatment (Blacha, 1982).

Bobath (1971) emphasized that only those techniques that bring about an immediate improvement of tone and active movement during a treatment session, should be used for a specific child.

Whether the tone will be influenced over time will depend on how successfully the "normal postural reflex mechanism and normal sequences of movement can be developed" (Bobath and Bobath, 1964, p7).

Facilitation of normal basic postural reactions

When a movement of any part of the body takes place, disturbances in equilibrium of the body occur and therefore the rest of the body is constantly changing to achieve postural adjustment during the movement (Bobath and Bobath, 1957). These changes are automatic and usually not conscious. They consist of compensatory movements or just fluctuations in muscle tone. In either case the maintenance of posture is dynamic, not static (Bobath and Bobath, 1964).

Postural reactions are co-ordinated in patterns in the normal person. They start before a voluntary movement occurs and are active during the movement (Bobath, 1969).

Before any functional skill can develop a normal postural reflex mechanism needs to be present. This consists of two types of automatic reactions - the righting and equilibrium reactions which develop in a definite sequence in the normal child (Bobath, 1964). This sequence has to be kept in mind in treatment.

As abnormal postural patterns are inhibited and tone normalized normal active automatic reactions have to be elicited. The older child also needs to be helped to acquire the most important postural patterns that he has missed in his development (Bobath, 1964).

Automatic and voluntary movement

Bobath and Bobath (1964) pointed out the continuum of movement from least automatic to most automatic. This is important to consider in the treatment of cerebral palsied children since the more one has to think about doing something the more effort is required. Increased effort increases spasticity in a spastic child. In treatment the aim is, therefore, to lay down foundations of automatic movement and gradually to build on these (Mohr, 1981).

Bobath and Bobath (1964) developed facilitation techniques "to obtain active automatic movements from the child". The facilitation allows the child to establish these patterns of automatic movement so that he can later use them at will.

One of the ways in which facilitation of the basic patterns of movement can be achieved is by weightshifting. Automatic movements like equilibrium reactions cannot be done without weightshifting. Integration of control of flexors and extensors is necessary to allow elongation on the weightbearing side and shortening on the non weightbearing side. Before a limb can be used in function it has to be relieved of taking weight and weightshifting therefore has to take place. Weightshifting can also be used to stimulate, for example, lateral righting reactions. It is important to remember that different sensory stimuli are needed for the various righting reactions. Asymmetrical righting (body on body) reactions need a tactile-kinesthetic stimulus, labyrinthine righting needs a vestibular stimulus; and optical righting needs a visual stimulus (Blacha, 1983).

Mohr (1981) explained that every movement performed has a foundation of automatic movement. All movements can be seen as being automatic, less automatic or voluntary. Even voluntary movements are based on a background of "automatic postural reaction patterns" (Bobath,1969,p19). Righting and equilibrium reactions are completely automatic. (The body has an innate ability to respond to gravity). On the other hand learning a new skill like writing or dressing is voluntary until it becomes automatic to a certain extent (Mohr, 1981). When it has become automatic, volition is only needed to initiate the task, the rest is automatic (Mohr, 1981). Each task of movement, therefore, has some automatic component. When a normal child wants to pick up a toy, his decision to pick up the toy is voluntary but the rest is automatic.

When a coach in sport teaches a new skill he will concentrate on one component until that becomes automatic before concentrating on the next component. Mohr says that a person can only direct cortical control to one component of movement at a time, the rest has to be automatic (Mohr, 1981). Kottke and his coworkers state that attention is limited to one activity at a time with the ability to shift attention but not more frequently than three times a second (1978).

<u>Eliciting more automatic to less automatic movement in treatment</u>

When applying the above in treatment, the least amount of volition possible should be used during treatment. If a child automatically reaches out for a toy there is less volition than when the child is asked to reach out for the toy. More volition may increase tone more, due to increased effort. However, the volition required can be graded as the child becomes more able (Mohr, 1981).

Sometimes even the thought of an activity may bring on the existing abnormal pattern of movement. Such an activity should, therefore, be avoided in treatment (Rast, 1984b). There is also a difference between having to think how an activity should be done and simply doing it as the activity invites. Structuring the activity to elicit just the right movement after the upper limb has been prepared to cope with this specific movement is, therefore, often one of the biggest challenges for the occupational therapist.

Blacha (1982) and Rast (1984b) underline the fact that the therapist must be sure that the underlying automatic skills, for example, equilibrium reactions are there, before requiring the child to do more complex voluntary movement skills. It is, therefore, important to supply correct preparation of postural mechanism to be 'background patterns' for the experience of new voluntary components of movements. Blacha (1983b) believes that the child learns fastest if given visual cueing reinforced by kinesthetic feedback which allows the child to know whether his movements are right or wrong. It is important to teach the subject to internalise the normal experience of movement learnt in treatment to be able to carry this over to activity. In order to do this (Blacha (1983a) considers the following factors to be important for treatment:-

- The sensorimotor capacity of the child is utilized to elicit automatic movements that can be used in function.
- The environment - External cueing, for example, visual or cognitive can be brought into treatment. The use of toys or activities to carry over movement into function and problem solving of subskills that eventually lead to functional skills can be used as part of the treatment.
- Shaping - The therapist needs to start with what is automatic for the child and gradually modify this as he begins to handle additional movement patterns.
- Reinforcement - The therapist needs to let the child know when he responds correctly. She can give him additional feedback, by, for instance, approximation of the specific joint(s) in the right direction.
- Fading - As the child is able to respond to specific handling the cues can be reduced or changed, for example, from proximal to distal or by changing the surface. This prevents the child from becoming over-dependent on the handling and encourages carry over of normal patterns achieved in various situations.

Facilitation and inhibition to achieve more complex movement sequences

Blacha (1983b) believes that treatment should start at the problem area. When working on hand-function she works very specifically on the scapulae (after preparation of trunk and neck as needed). She uses traction to inhibit spasticity and uses approximations in a very small and specific range to encourage specific muscles to work. Approximation also helps to dissociate and mobilise. She uses this, for example, on the gleno humeral joint, the elbow and the wrist.

While working on the more distal joints she makes sure that the scapula remains stable on the trunk by her handling techniques.

As soon as the body part is in a more normal position she brings in weightshift, equilibrium reactions and then weightbearing and moving the body over the limb.

Compression of the shoulder joint, weightshift and weightbearing are also used by Erhardt to prepare the shoulder for reaching and other functions.

Levitt gives attention to regard, reach, grasp, manipulation and release in her training of hand-function. She uses specific methods of inhibition or facilitation to achieve, for example, hand opening. Specific objects (reinforced by hands on treatment) are used to position the child's hand, wrist and arm as normally as possible during simple activities. She starts with positions that are easier for the child and grades from there.

Vision is used together with training of grasp. She encourages bilateral symmetrical and asymmetrical as well as reciprocal movement. She tries to encourage the child to perform the possible daily activities in as normal a way as possible by facilitation and trying to inhibit abnormal patterns.

Rast brings in components of movement that may be part of an activity that needs to be done by the child at a later stage, into treatment. She also goes into the child's environment to help the child and/or mother and/or teacher to find the most therapeutic ways of doing activities in his everyday life. A simple example may be to ensure that the diplegic child needs to reach out to some materials in class instead of just working in a close space in front. The hemiplegic child may be helped by placing the affected arm forward on dycem or to put his hand over a large sponge-covered roll placed horizontally on the table (Rast, 1984b).

Erhardt (1982) prescribed very specific activities to meet every need that showed up in her extensive hand-function assessment of the child. She, for example, set goals to improve hand-function to achieve more independence in school activities. For each goal she set objectives that included a specific type of grasp or a particular way of using the upper limb for several tasks. These were to be practised until a specific level of function was achieved. The activity was designed to elicit the particular movements needed and, where necessary, an adult had to facilitate such a movement until it could be done independently. In this way Erhardt made use of a functional object, as part of an activity, to elicit the desired movements.

Gliner (1985) points out that many skills of movement include an object, for example, kicking requires a ball. Developing such a skill can not be considered without bringing in the object. The object needs to be present to elicit the skilled movement and often the properties of the object chosen helps to structure the movement required.

Levitt (1977) also pays attention to the thumb. She suggests when the thumb tends to be in adduction to encourage the child to do all activities towards the thumb side and to encourage radial grasping. If the thumb is in the child's palm she externally rotates the shoulder or supinates the hand and then brings out the thumb from the carpometacarpal joint, to place the hand over a suitable surface or toy. Some children tend to use the thumb better when the hand is at the midline.

Although there are many controversial opinions about the use of splints to improve the position of the thumb some therapists have found this useful in certain instances. Exner (1976) found that of twelve children wearing a short opponens splint (described by various authors) two improved in bilateral handuse and three improved in grasp. This was especially useful in a child with limited grasp due to an adducted thumb. The thumb had to be well controlled at the carpometacarpal and the metacarpophalangeal joints not just distally.

Irwin Carruthers (1984) emphasizes that the aims of splinting should be to provide more normal sensorimotor experience through optimal feedback from that body part, which will encourage more normal movement patterns.

Once the child has had a chance to get the feeling of a position it may be sufficient to remind the child, for example, to get his thumb into the better position.

Eventually one could merely wait and expect the child to reassume the correct position himself. This also helps the child later to do more self inhibition in other situations (Rast, 1984b).

In spite of the above work on hand-function occupational therapists have not been sufficiently aware of all the aspects contributing to hand-function. They have, therefore, seldom treated the cerebral palsied child with the specific aim of improving hand-function.

CHAPTER 3 RESEARCH DESIGN

This study was conducted at the Eros School for Cerebral Palsied children in Bridgetown, Cape, during the months of March to September, 1983.

All the children in the Pre-school classes who met the following criteria were included in the study:-

- a diagnosis of spastic hemiplegia or diplegia;
- able to walk;
- one upper limb more involved than the other;
- some voluntary power in the more affected limb.

These children were assessed using the assessment procedure described below. Assessment results were used to pair the children by matching the following criteria in sequence of importance:-

- total score of the Erhardt assessment ;
- severity of involvement ;
- age ;
- intelligence ;
- stereognosis ;
- motivation for treatment as judged by the occupational therapist treating the child ;
- sex.

Nine pairs were well balanced and the remaining two children G.L. and C.J. were considered to be a tenth pair in spite of bigger differences (See Table 1, p.74).

One child of each pair was randomly selected for the experimental treatment while the remaining children formed the control group. In the tenth group the child whose programme at school would be less disrupted was chosen to be part of the experimental group. Of the twenty children only one child, G.L., acquired the hemiplegia at two years of age after a motor car accident. The other children all had cerebral palsy from birth.

TABLE 1

MATCHED PAIRS

Experimental Group	Sex	Age (Months)	IQ	*TJ	Aff. Hand	Hemi Di	Sev	Ster	Mot	E Assmt Total	Control Group	Sex	Age (Months)	IQ	TJ	Aff. Hand	Hemi Di	Sev	Ster	Mot	E Assmt Total
GL	M	93	76	1-2	L	H	0	1	1	147	CJ	F	65	88	1-2	R	H	1	3	2	182
AD	M	60	65	1	R	H	1	1	1	205	CP	M	70	66	2-3	L	D	0	1	2	216
JW	M	68	91	3	R	H	1	1	2	231	ST	M	68	71	1-2	L	H	1	4	3	247
CR	M	72	70	2	R	H	2	5	3	287	SM	F	73	70	2	L	H	2	5	2	278
LS	F	65	83	2	R	H	1	2	3	227	DK	F	73	90	2	L	H	1	2	3	237
RF	M	82	77	2	R	H	1	5	3	226	FS	M	89	69	2	L	H	1	2	2	224
IM	F	77	68	1	L	H	1	0	3	235	EJ	F	77	84	2	L	H	1	5	3	220
DD	M	76	57	2	L	H	1	2	1	205	BJ	M	76	92	1	L	H	1	0	1	212
RE	M	94	72	2	L	D	2	5	3	270	EL	M	88	72	1	L	H	1	5	2	251
NJ	F	92	64	1	R	D	2	5	1	287	JG	F	90	72	3	L	H	2	3	1	279
Total	7M 3F				6R 4L	8H 2D						5M 5F				1R 9L	9H 1D				
Ave.		76,2	71,9				1,2	3,22	2,33	241,3			78,2	76,2				1,1	3,33	2,11	240,4

Explanation of Table 1

Severity - 0 severe, 1 moderate, 2 mild, 3 mormal.
Motivation - 0 very poor, 1 poor, 2 fair and 3 good.
Stereognosis - number of objects identified with the affected hand.

* Refer to List of Abbreviations on p x and xi for all Tables and Figures.

1. <u>Venue for Occupational Therapy Assessment and Treatment</u>

A well lit room of approximately 3 x 5 metres was used for all the assessments and treatments. This room was carpeted, had a row of windows and two wall heaters on the one side, and a door and blank wall on the opposite side. Apart from a small one way mirror and a wash basin the other walls were also blank. The table was placed against the second wall. This wall was also used whenever activities were fixed to a vertical surface.

Equipment used for the assessment consisted of a firm sponge block (20 cm x 25 cm x 150 cm) to sit on while undressing, a small table (47 cm high) and chair (30 cm high) to be used for all table top activities; and an assessment kit. The therapists also sat on small chairs for this part of the assessment. The other assessments were all done on the carpeted floor.

For the treatments additional equipment was used as needed for each specific session. This consisted of three treatment balls, red (diameter 76 cm), orange (diameter 50 cm) and yellow (diameter 40 cm), a large treatment roll (diameter 30 cm), the above block and various types of equipment and materials used for play activities.

<u>Assessment kit:-</u>

<u>Erhardt assessment</u>

One wooden dowel 2 cm x 16 cm.
One wooden cube 3 cc.
Monkey nuts - whole - with red skin to be clearly visible.
Containers with diameter 8 cm (x 10 cm), 6 cm (x 7 cm), 3 cm (x 7 cm) and 2 cm (x 4½ cm).
Plastic box with fitted lid 3.5 cc to be used for combining objects.

<u>Additional items.</u>

Pencil with contrasting rubber for eye movements.
Two of each of the following:- marble (1.5 cm), button (5 cm), plastic cotton reel (3.6 x 3 cm), cube (3 cc), safety pin

(6 m x 1 cm) and one of each of a paper clip and a plastic peg (1 cm x 3 cm) for stereognosis.

2. Assessment

For this study sections of the Erhardt Developmental Prehension Assessment were selected to look at specific factors in approach, grasp, manipulation and release. Protective extension was included since this is directly related to weightbearing on the hand and brings in an aspect of balance which is important in hand-function.

2.1. The Erhardt Assessment

This assessment is divided into three sections.

Section 1 Primary Involuntary Arm-Hand Patterns (Positional Reflexive)

Of this section only part of one aspect was selected, namely,

Placing Responses (1e) (3 - 12 months) in order to assess protective extension.

Sub-sections 1a - d (the arms at rest in supine and prone, the asymmetrical tonic neck reflex and grasping responses); the first part of e (placing responses) and the whole of f (avoiding responses) were omitted because they were not of sufficient application to the older, lesser involved cerebral palsied child.

Section 2 Primary Voluntary Movements (Cognitively Directed)

Of them the following were selected:-

The arms on approach (sitting) (2c) to assess ability and quality of reaching for objects (complete).

Grasp of the Cube (2e) (complete).

Grasp of the pellet (2f) (complete).

Manipulation skills (Prehension Schema) (2g) - only the parts related to the cube and pellet were used (7 - 15 months).

Release of the Dowel or Cube (2h) - only parts related to the cube were included (7 - 12 months).

Release of the Pellet (2i) - (complete).

Sub-sections 2a, b and c concern the arms on approach in three different positions. Supine and prone are seldom used in children of this age group. Arms on approach in sitting (2c) was thus selected. Grasp, manipulation and release of the dowel (sub-sections 2d and the last parts of 2g and 2h) does not give sufficiently different information from the comparative sections using a cube, and were therefore omitted.

Section 3 Prewriting Skills

This section was not included since this was more applicable to the better hand of a hemiplegic child.
To be able to score results the following values were assigned to Erhardt's scoring system:- (also see explanation on p.137a)

Pattern not present (-) was given a value of 0;
Emerging or abnormal pattern not well integrated (±) a value of 1;
Well integrated normal pattern (+) a value of 2;
Well integrated but transitional pattern replaced by a more mature pattern (H) a value of 3.

Items on the Erhardt Assessment were categorised, labelled, and colour coded to enable comparison of similar functions and assess the level of a specific function more easily. Each category was given a symbol for ease of scoring. (See assessment form p 130 appendix A).

The only procedure for administering the test consisted of:-
"1. Present stimuli and/or observe child.
2. Record Pattern Component scores, lowest levels first." More detail was thus added to each section of the form in an attempt to maintain optimal uniformity of presentation and scoring (See p 133, 134 and 137 as well as explanatory notes p 137a).

Omitting sections and aspects of the assessment naturally affects its validity as a representational sample. Erhardt in her inter-rater reliability assessments, however, also did not include all 100 items for every child. Items which were shorter than the Erhardt items would have been, were added to bring in the additional information needed for pairing and treatment of the children.

2.2. Additional items:-

The additional parts of the assessment were scored on a five point scale 0 - 4 or 0 - 5 with 4 (or 5 in stereognosis) being no limitation in all cases.
Because intelligence tests had been done several years previously, the teacher's judgement of intellectual functioning was added.

Each child's teacher was requested to complete a form for the child in order to assess the following on a 5 point scale:- intelligence, ability to do handwork, ability to draw, ability to concentrate and motivation to try and do. All assessments were repeated at the end of the treatment period. (See Appendix B)

The occupational therapist treating the child was asked to assess from her experience with the child his motivation for treatment, distractability and praxis as noticed in everyday tasks.

The only functional task included in the assessment was taking off the child's garment (T.O.G.). This was assessed by observing whether the child assists by positioning his affected shoulder, elbow, wrist and hand in any way, whether he holds down the garment, grasps the garment, extends his wrist, brings his thumb out of his hand and supinates his hand appropriately as he takes off the garment. One point was given for each position or action that was present.

Scapular movement was observed by asking the child to crawl. He was thereafter observed lifting his arms while sitting on the floor. If necessary, the therapist palpated the scapula. An attempt was made to observe scapular movement on the trunk, dissociation between the scapula and humerus, and the amount of reciprocal movement of the scapulae during crawling.

Associated reactions to the affected upper limb were observed and judged according to the amount of movement or tension elicited while the child was in supine and asked to lift his head, abduct one then the other leg, abduct, then elevate the unaffected arm, squeeze the fingers of the therapist, and place a pellet inside a small container with the normal hand.

Symmetry was observed after requesting (and helping if necessary) the child to lie as symmetrically as possible in the supine position.

Tone was assessed in supine by moving the various body parts passively to feel the tone, comparing the two sides of the body.

Two aspects of eye movements were assessed in sitting, namely pursuit and convergence. A pencil with a contrasting coloured rubber was used except in a few cases where the attention of the child was very poor and a little animal on a pencil was used to keep the child's attention. The pencil was moved horizontally, vertically and diagonally approximately 30 cm from the child's eyes and then brought in to his nose to assess convergence.

Proprioception was assessed by moving specific fingers up or down by holding the finger at both sides of the distal interphalangeal joint so that the child could judge and report the position.

Stereognosis was assessed by using a marble, cube, button, safety pin and cotton reel in a set sequence for the better hand and then in a different set sequence for the affected hand. Vision was occluded by bringing a file over the child's hands. A second set of objects was supplied so that the verbal ability of the child would not limit his ability to respond correctly.

Severity was judged to be severe (o) if use of the hand was definitely an effort; moderate (1) if the hand could be used more freely but with definite abnormal patterns; mild (2) if the hand could at times be used in close to normal patterns.

3. Reliability of the Assessment

All assessments were carried out together by the candidate and one other occupational therapist. Two occupational therapists assisted in the assessment of ten children each before treatment and the same ten children after the treatment period.

3.1. Inter-rater reliability

One of the pre-assessments of each therapist was recorded separately by the candidate and the other therapist and later discussed to come to a final decision (see results in Appendix C).

The therapist H.B. and the candidate initially agreed with 32 of the 40 items - that means in 80% of the cases. The therapist B.E. and the candidate agreed 29 times which means there was 72.5% agreement.

3.2. Test-retest reliability

Two children outside the study were assessed using the above assessment on a Saturday morning at the school hostel. This assessment was repeated with the same children the following Saturday. (See results in Appendix D).

The first and second performances were exactly the same for 16 items, that means 65% of items for K.F. and 22 items, which means 55% of items for R.L. Forty items were retested.

The differences were slight except in a few instances, for example, K.F. who managed to manipulate the pellet with less dependence on vision the second time. R.L. twice had his wrist extended instead of flexed the second time; was able to release a cube initially in

TABLE 2

PLANNED TREATMENTS PER WEEK FOR EXPERIMENTAL PERIOD

Exp. Group	PT	ST	OT	Exp	Total	Control Group	PT	ST	OT	Exp	Total
GL	1	0	1 Gr	1	2+1Gr	CJ	,5	0	2,5	0	3
AD	2	2	2	1	7	CP	2	2	3	0	7
JW	1	1	1	1	4	ST	2	1	2	0	5
CR	0	0	3 Gr	1	1+3Gr	SM	,5	0	3 Gr	0	,5+3Gr
LS	1	0	1*	1	3	DK	1	0	1+1 Gr	0	2+1Gr
RF	0	0	1	1	2	FS	0	2	1	0	3
IM	0	0	1*	1	2	EJ	,5	0	1	0	1,5
DD	1	0	1+1Gr	1	3+1Gr	BJ	2Gr	0	1,5	0	1,5+2Gr
RE	2	0	1	1	4	EL	2	0	2**	0	4
NJ	1	1Gr	1 Gr	1	2+2Gr	JG	1	2	1Gr	0	3+1Gr
	9	3+1Gr	8+6Gr	10	30+7Gr		9,5+2Gr	7	13,5+5Gr	0	30,5+7Gr

The total individual treatments of the experimental group were therefore to be ,5 treatments less than the control group and the treatments in a group were to be equal for both groups.

* 1 OT treatment omitted to accommodate experimental treatment. (See p 82).

** 1 OT treatment added to balance experimental group. (See p 82).

TABLE 3

ACTUAL TREATMENTS PER WEEK DURING EXPERIMENTAL PERIOD

	PT	ST	OT	Exp.	Ind. TOTAL	Gr. TOTAL
GL	1		1Gr	1	2	1
AD	2		1	1	4	
JW	1		1	1	3	
CR	0		1	1	2	
LS	1		1,5	1	3,5	
RF	1		1	1	3	
IM	1,5		1	1	3,5	
DD	1,5		1	1	3,5	
RE	1		1	1	3	
NJ	1,5	1,5	1Gr	1	3,5	1
Total	11,5	1,5	8,5	10	31	2
Ave Ind.	1,15	0,15	0,85	1,0	3,1	
Ave Gr.			0,2			0,2

	PT	ST	OT	Exp.	Ind. TOTAL	Gr. TOTAL
CJ	1		1	0	2	
CP	2	2	1	0	5	
ST	2	1	2	0	5	
SM	1		0,5	0	1,5	
DK	1		1Gr	0	1,0	1
FS	0,5	1	2	0	3,5	
EJ	1		1	0	2	
BJ	1,5		1	0	2,5	
EL	1	1,5	1	0	3,5	
JG	1	1	1Gr	0	2	1
	12	6,5	9,5	0	28	2
	1,2	0,65	0,95	0	2,8	
			0,2			0,2

The actual total individual treatments of the experimental group were therefore 0,3 treatments more than the control group (i.e. 3,1 - 2,8) and the total of group treatments were equal for both groups (i.e. both 0,2).

a small container in a controlled way by taking special care (which he did not do the second time) and was able to transfer the pellet using his fingers instead of his whole hand the second time.

The first assessments were done shortly after breakfast. The second assessment could, however, not be done at the same time since the children were watching a video which interested them greatly when the candidate arrived. This assessment was therefore done in the afternoon.

4. Treatment

Each child continued his or her normal school programme. This included physiotherapy, speech therapy and occupational therapy as required. When the child was seen in therapy together with one or more other children this was added separately as group treatment in addition to the individual treatment. The treatment received by each member of each pair was balanced as far as possible to ensure that the experimental group would not receive an additional treatment period. In a few cases a therapist was asked to take a child of the control group once per week more or a child of the experimental group once per week less to achieve this balance (See Table 2, p.80).

However, due to many day to day factors in a school the treatments children received were not exactly as planned. The approximate average of treatment per week received during the experimental period can be seen on Table 3 (p 81). According to this the experimental group received a mean of 0,3 treatments more per week over this period.

Speech therapy sessions included inhibition of tone and use of handfunction as well as oral stimulation for C.P. and speech and language training for the other five children treated.

Physiotherapy consisted mostly of normalisation of tone and facilitation of normal movement patterns. The lower limbs were included for all children except L.S. The upper limbs were included for all children except J.G. in the control group. (All children received physiotherapy except C.R. of the experimental group. He was the most minimally involved child as can be seen by his Erhardt assessment results).

In occupational therapy (See Table 4, p.82a) all children in the study received perceptual training. Six of the experimental and five of the control group also received other developmental stimulation which would include perceptual motor aspects. Six of the experimental and five of the control group had training in activities of daily living, and four of the experimental group and six of the control group had treatment

TABLE 4 **ASPECTS COVERED IN OCCUPATIONAL THERAPY TREATMENT**

Exp.	P	D	ADL	UL	Control	P	D	ADL	UL
GL	×				CJ	×			
AD	×	×	×	×	CP	×	×	×	×
JW	×				ST	×		×	×
CR	×	×	×		SM	×	×	×	
LS	×		×		DK	×			
RF	×	×		×	FS	×	×	×	×
IM	×	×	×	×	EJ	×	×	×	×
DD	×	×	×		BJ	×	×		×
RE	×	×	×	×	EL	×			×
NJ	×				JG	×			
Total	10	6	6	4		10	5	5	6

for their upper limbs included as part of the sessions.

The experimental children received one experimental treatment per week for 30 minutes each for 12 sessions. This period was interrupted by a holiday period of three weeks.

One child in the experimental group D.D. and one in the control group C.P. underwent Tendon Achilles lengthening during this time and were absent from treatment for an additional 3 weeks over this period.

4.1. General principles of treatment

In designing a treatment programme to improve hand-function neuro-developmental principles had to be considered, namely:-

1. Normalization of tone at the beginning and throughout the session.
2. Facilitation of normal postural reactions including equilibrium reactions and protective extension.
3. Facilitation and inhibition to achieve more complex movement sequences. This included
   - an attempt to achieve more normal mobility and stability of the shoulder.
   - an attempt to improve proprioception and sensation by weight-bearing activities on the open hand (with well aligned arm) on different textures.
   - an attempt to bring in patterns of release before patterns of manipulation or grasp were encouraged.
   - an attempt to elicit selected manipulation and grasp patterns avoiding abnormal movement as far as possible.

Various types of play were incorporated into each session.

1) Symbolic play was used together with normalisation of tone for some younger children.
2) Games with rules (like noughts and crosses and skittles) were used mostly with reaching, shoulder mobilisation or release activities.
3) Games of construction were used especially during manipulation and grasp and release activities.

4.2. Principles during each session

1. All patterns of movement were kept as "normal" as possible by normalization of tone throughout the session.
2. An attempt was made to commence treatment with movement which the child could perform at an automatic level and to progress

towards movement which was less automatic.

3. Effort that would increase tone was avoided as far as possible.
4. Static activities of the hand were used as far as possible only in conjunction with mobility of the shoulder.
5. Co-ordination of hands with vision was used to reinforce correct movement patterns of the hand and to improve eye-hand co-ordination.
6. Associated reactions of the abnormal side by activity of the "normal" side, was avoided as far as possible.
7. Play activities were adapted and structured to try and meet each child's specific treatment needs - for example to elicit correct movement patterns needed by the individual child.
8. Play activities were presented to try and capture the interest of each child according to the personality and abilities of the child.
9. The specific activities used during each session and for each following session varied in order to achieve optimal interest and attention.

Both neurodevelopmental needs and play interests of the group of children were considered before deciding on the outline of each treatment session.

4.3. Outline of each treatment session

Each treatment session consisted of the following parts:-

A. An activity (mostly done on a treatment ball) to try and achieve normalisation of tone of the trunk. Equilibrium reactions and protective extension were also elicited as appropriate.

B. One or more activities were used to encourage:-
   1) Full movement of the affected shoulder.
   2) Stability of the shoulder and scapula on one side with mobility on the other side and vice versa.
   3) Mobile weightbearing on the open hand of the affected side.
   4) Release of an object on the affected side.

C. An activity to encourage grasp and/or manipulation with special attention to the thumb (unilateral, bilateral and reciprocal activities were included). See appendix E for an example of activities used during each phase of the twelve treatment sessions.

In treatment A the movement on the ball was enjoyable in itself. By bringing in unexpected moves or requirements or sometimes imaginative games for the younger children motivation and participation was encouraged without additional activity.

In an attempt to keep tone as normal as possible during the activity for grasp and manipulation in C, use was made of

1) specific sitting positions;

2) position of work surface and other objects to be used;

3) shape of objects to be used (for example, to encourage extension of the metacarpophalangeal and interphalangeal joints of the thumb);
4) activities done with an open hand were included and
5) static grasp was avoided. No additional hands-on control of the pelvis, shoulder or any other part was added. This was done in order to achieve a near normal daily situation for the child and thus to achieve the maximum carry over to the daily functioning for each child.

For every treatment, play principles were used throughout the session to ensure that the child was having fun. However, care was taken not to excite the child too much since this tended to raise the child's muscle tone.

Traditional occupational therapy treatment for handfunction often included aspects similar to section A, B3 and some type of grasp and release or some type of fine motor activity. This was also done at Eros.

In an attempt to fill perceived gaps in treatment (and to meet the needs of the children in the study), activities of play to achieve mobility and stability of the shoulder and gross release patterns involving the whole hand, were added to the experimental treatment programme.

In Section C activities of grasp and release were kept to a minimum or controlled as far as possible (See explanation of C above).

An attempt was made to select play activities which

- were applicable to the age and interest of the children (They were all at a preschool level and their interests coincided with those of 5 - 6 year old children. See p 60);
- had simple physical requirements, (for example, the use of simple finger movements rather than grasp and release);
- had minimal requirements of effort; and
- were similar to activities done in class to try and achieve maximal carry over of good movement patterns achieved.

Pre and post treatment scores of each category in every section were compared for both groups of children to determine whether statistically significant improvement had resulted from the experimental treatment. The total pre and post test scores were also compared for the two groups.

A 0,05 level of significance was used for all the results.

T tests and other parametric methods were used to analyse the results but were not considered sufficient because of the small size of the sample.

In addition, therefore, the nonparametric test, the Wilcoxon matched-pairs signed ranks test, was used to confirm the results.

CHAPTER 4 RESULTS

Implementation

The research design was carried out as planned. Modifications were mainly sorted out and included in the research design before the experimental period started. At the second assessment one item that was not found useful enough was left out. This was "Getting up to sit on a chair".

1. Results of the Assessment

There were two sets of data. Twentysix items were from the Erhardt part and sixteen items were from the additional part of the assessment. There was not a significant difference between the experimental and control groups when the sum of the mean of differences between pre and post experimental scores were compared. There was, however, a trend in favour of the experimental group (See Fig. 1 and 2).

During the experimental period the candidate became more aware of finer differences in position and movement due to her concentration on the upper limb in the treatment sessions. Both the other two therapists during this time completed an advanced neurodevelopmental course where special attention was paid to the upper limb. Reassessment thus tended to be judged more strictly than the initial assessment. This led to an appearance of deterioration of the results of both groups. Results in the test-retest situation did not show this effect since the assessments were done within a week of one another.

The sum of the mean of differences between the first and second assessments of the Erhardt items (See Figure 1, P. 89) showed significant deterioration in the control group. (A mean of -7.1 versus -1.2 for the experimental group)

The experimental group improved more or deteriorated less than the control group in fourteen of the twentysix items. The control group was ahead in seven items and the mean deterioration or improvement was the same for both groups in five items.

In the additional items (See Figure 2, P.90) the mean of change for

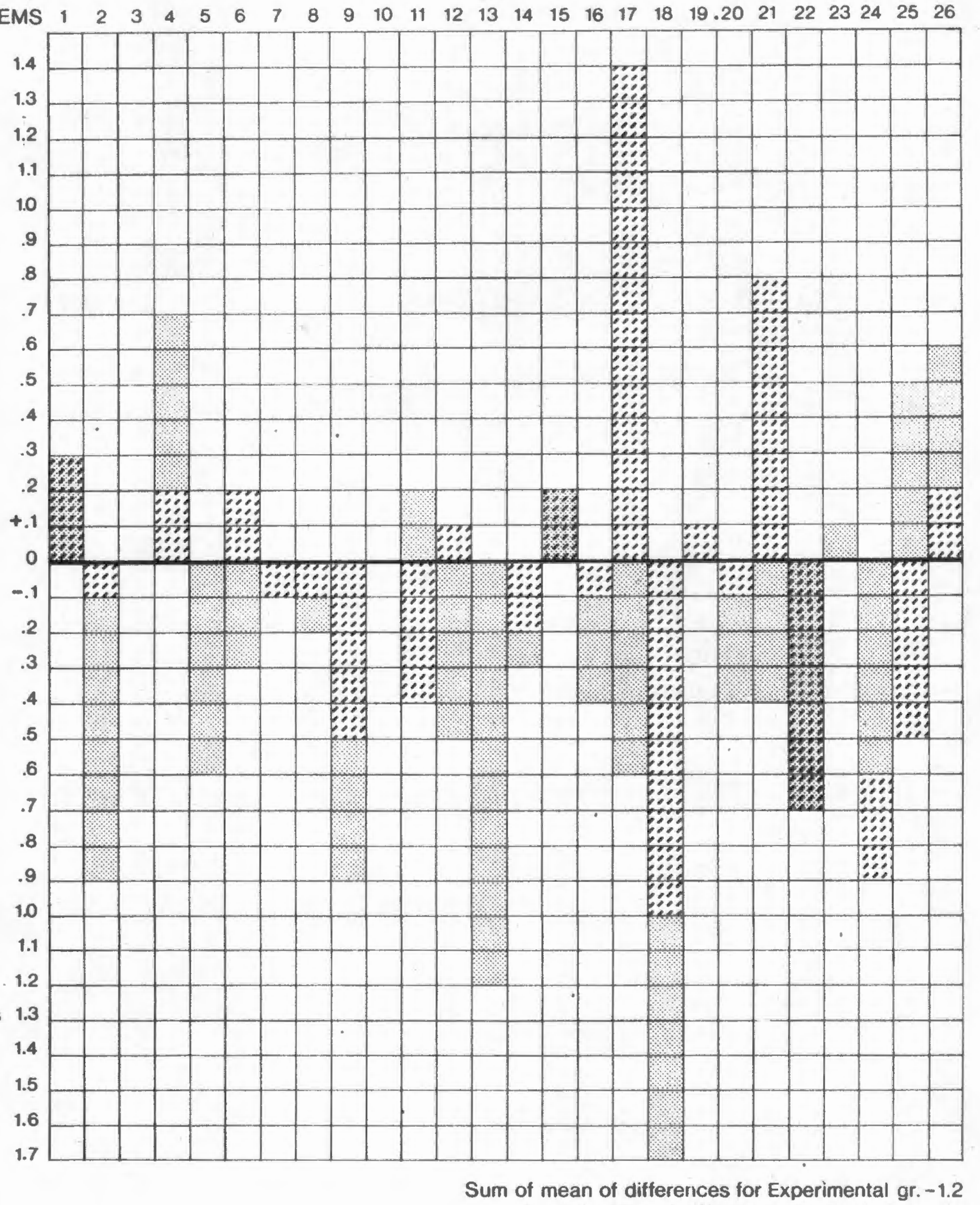


Figure 1

Mean of differences between first and second assessments comparing Erhardt items for
Experimental
and Control groups

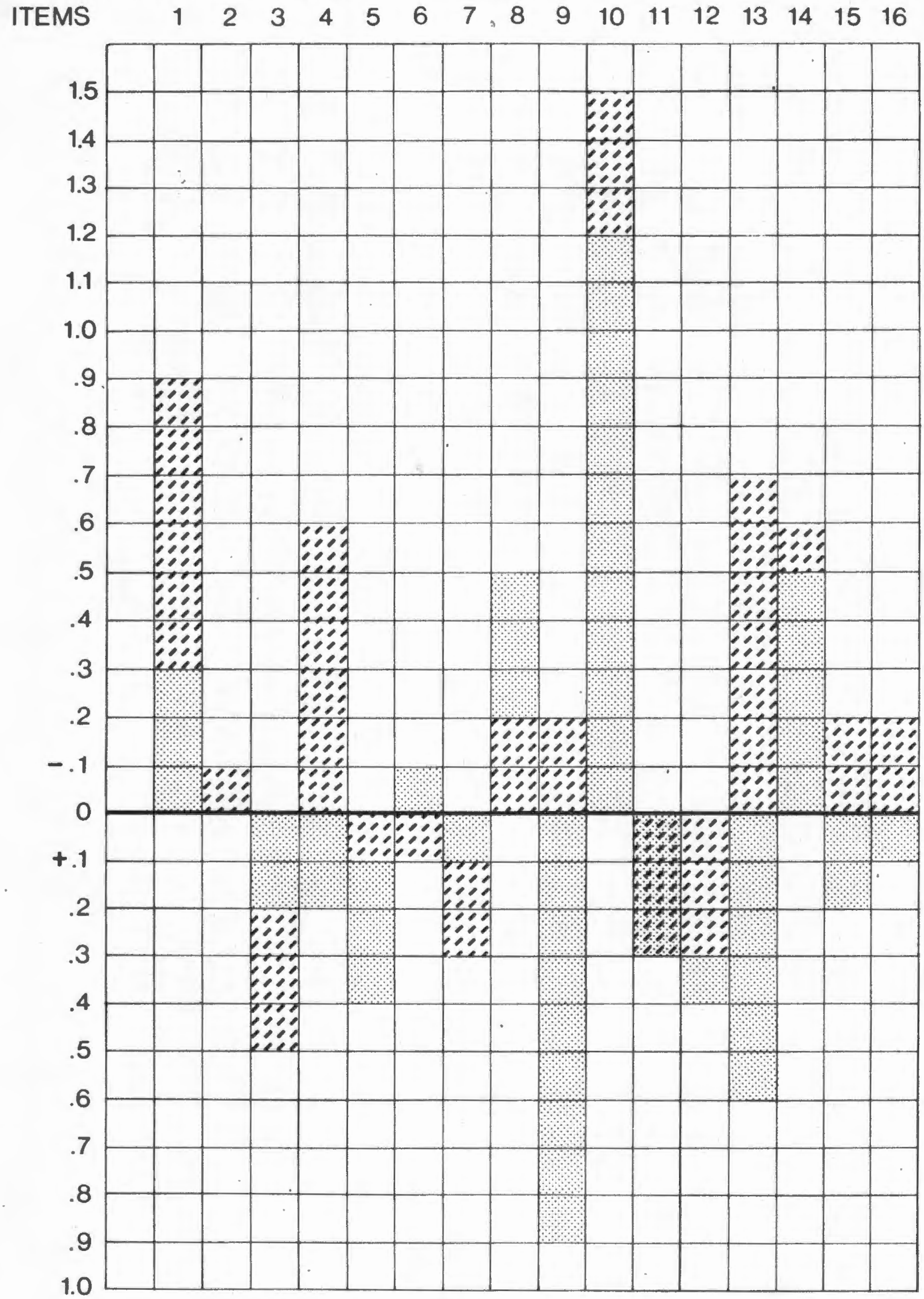
Sum of mean of differences for Experimental gr. -1.2
Sum of mean of differences for Control gr. -7.1

EXPLANATION OF FIG. 1

1. Protective Extension. = E + C + 0.3
2. Approach - reach + E - 0.1, C - 0.9
3. Approach. = E + C 0.0
4. Approach - position of elbow. - E + 0.2, C + 0.7
5. Approach - position of forearm. + E + 0.0, C - 0.6
6. Approach - position of wrist. + E + 0.2, C - 0.3
7. Approach - position of hand. - E - 0.1, C + 0.0
8. Grasp cube. + E - 0.1, C - 0.2
9. Grasp cube- position of wrist. + E - 0.5, C - 0.9
10. Grasp cube - position of thumb. = E + C = 0.0
11. Grasp pellet. - E - 0.4, C + 0.2
12. Grasp pellet - position of thumb. + E + 0.1, C - 0.5
13. Manipulation of Cube. + E 0.0, C - 1.2
14. Manipulation of cube - vision. + E - 0.2, C - 0.3
15. Dropping and Throwing of cube. = E + C + 0.2
16. Generalisation with pellet. + E - 0.1, C - 0.4
17. Manipulation of pellet. + E + 1.4, C - 0.6
18. Manipulation of pellet - vision. + E - 1.0, C - 1.7
19. Bilateral manipulation of pellet. + E + 0.1, C + 0.0
20. Differentiation of shoulder elb. & w. + E - 0.1, C - 0.4
21. Release cube. + E + 0.3, C - 0.4
22. Release cube - position of wrist. = E + C - 0.7
23. Transfer of cube. - E + 0.0, C + 0.1
24. Release pellet. - E - 0.9, C - 0.6
25. Release of pellet - position of wrist. - E - 0.5, C + 0.5
26. Transfer of pellet. - E + 0.2, C + 0.6

Figure 2

Mean of differences between first and second assessments comparing additional items for Experimental and Control groups



Sum of mean of differences for Experimental Gr +3.5
Sum of mean of differences for Control Gr −0.7

Control Group   Experimental Group

EXPLANATION OF FIG. 2

1. Motivation. (Judgement of Occ. Therapist) + E + 0.9, C + 0.3
2. Concentration. (" " " ") + E + 0.1, C + 0.0
3. Praxis. (" " " ") - E - 0.5, C - 0.2
4. Taking off garment. + E + 0.6, C - 0.2
5. Scapula on trunk. + E - 0.1, C - 0.4
6. Gleno-humeral mobility. - E - 0.1, C + 0.1
7. Reciprocal mvt. of scapulae. - E - 0.4, C - 0.1
8. Tone at rest. - E + 0.2, C + 0.5
9. Symmetry. + E + 0.2, C - 0.9
10. Associated reactions. + E + 1.5, C + 1.2
11. Eyemovements - pursuit. = E + C - 0.3
12. Eyemovements - convergence. + E - 0.3, C - 0.4
13. Proprioception. + E + 0.7, C - 0.6
14. Stereognosis. + E. + 0.6, C + 0.5
15. Handwork (Teacher's judgement) + E + 0.2, C - 0.2
16. Drawing. (Teacher's judgement) + E + 0.2, C - 0.1

TABLE 5 SIGNIFICANT IMPROVEMENT OF EXPERIMENTAL GROUP IN COMPARISON WITH CONTROL GROUP

	Experimental mean			Control mean			Parametric	Non-Parametric
	Before	After	% incr./decr.	Before	After	% incr./decr.	P	P
Handling pellet in container	7,4	8,8	18,9% incr.	8,2	7,6	7,3% decr.	0,0048	0,0126
Handling pellet in container (excluding pokes thumb)	5,6	6,7	19,6% incr.	6,0	5,7	5,0% decr.	0,0246	0,0245
Total Manipulation of pellet (excluding mv)	12,2	13,5	10,7% incr.	13,6	12,2	10,3% decr.	0,0057	0,0066
Proprioception	2,7	3,4	25,9% incr.	3,5	2,9	17,1% decr.	0,0385	0,0412

the control group was -0,7 versus +3,5 for the experimental group. The mean of improvement for the experimental group was more than that of the control group for eleven of the sixteen additional items. The only items where the control group improved more or deteriorated less were praxis as judged by the child's therapist; mobility of the glenohumeral joint; reciprocal movement of the scapulae and tone at rest.

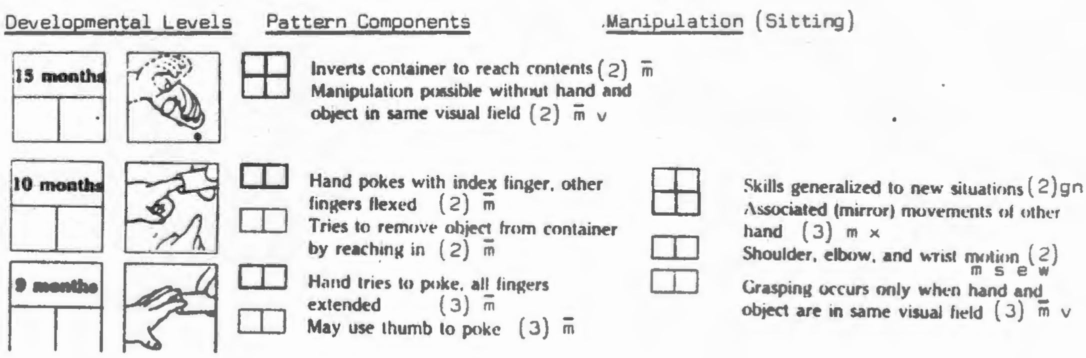
2. Significant Improvement of the Experimental Group in Comparison with the Control Group

The aspects in the assessment which were found to show a significant difference in favour of the experimental group were the following:- (See Table 5, P. 91)

2.1. Handling pellet in container ($\bar{m}$)

This consists of five sub-items as follows:-

1) may use thumb to poke;
2) hand tries to poke, all fingers extended;
3) tries to remove object from container by reaching in;
4) hand pokes with index finger, other fingers flexed;
5) visual dependence (mv) - not included (discussed later with item 7);
6) inverts container to reach contents.



Items 2 - 4 are all concerned with poking of the index finger, item 4 being the most mature response. Because one of the children, E.J., in the control group did not use her thumb to poke in the first assessment, she was given a top score of 3. The therapists assumed that she could do so satisfactorily but did not have to do it because she could use the more mature response of using her index finger. However, on reassessment she did use her thumb and could not use it altogether satisfactorily so she obtained a score of 1. In addition "poking of thumb" changed from one week to the next in both children in the test-retest situation. This section ($\bar{m}$) was therefore also considered without the item of poking the thumb.

2.2. Handling pellet in container excluding "may use thumb to poke" (pokes thumb) (See Table 5, p.91) was still found to be significantly better for the experimental group.

More dependence on vision was noticed on the second assessment for five of the experimental children and seven of the control children. Since this factor can be controversial (See discussion, p.103) dependence on vision (mv) was omitted when considering the items of the broader section of "Manipulation of the pellet".

2.3. Total manipulation of the pellet (excluding visual dependence (mv) (See Table 5, p.91) was significantly better for the experimental group and deteriorated significantly in the control group (See Table 7, p.95).

Apart from handling the pellet in the container the additional items in this section comprise:-
- shoulder, elbow and wrist motion (m) (item 8);
- associated mirror movements of other hand (while manipulating with the affected hand) (mx) (item 9);
- skills generalized to new situations (gn) (item 10).

2.4. Proprioception was significantly better for the experimental group. This was, however, heavily influenced by one child in the control group S.M. who could not understand the concept of up or down. In spite of this she was able to indicate the direction of movement on the first assessment but not on the second assessment. When she is given credit for the second assessment as shown in Table 14, Appendix F, there is still an average loss of 2 points for the control group which means a loss of 5,7% against the gain for the experimental group of 25,9%. One of the experimental children D.D. seemed to

TABLE 6 ASPECTS OF SIGNIFICANT IMPROVEMENT AND DETERIORATION OF EXPERIMENTAL GROUP

Improvement	Mean Before	After	% incr./decr.	P
Handling pellet in container ($\bar{m}$)	7,4	8,8	18,9% incr.	0,0095
Handling pellet in container (excluding pokes thumb)	5,6	6,7	19,6% incr.	0,0115
Total manipulation of pellet (excluding mv)	12,2	13,5	10,7% incr.	0,0575
Motivation judged by OT.	2,2	3,1	40,9% incr.	0,0100
Take off Garment	6,6	7,2	9,1% incr.	0,0510
Associated Reactions	19,1	20,6	7,9% incr.	0,0429
Deterioration				
Dependance on vision with manipulation (mv)	4,4	3,4	22,7% decr.	0,0319
Praxis as judged by OT	3,9	3,4	12,8% decr.	0,0150

TABLE 7 ASPECTS OF SIGNIFICANT IMPROVEMENT AND DETERIORATION OF CONTROL GROUP

Improvement	Mean Before	Mean After	% incr./decr.	P
Approach - position elbow	9,8	10,5	7,1% incr.	0,0445
Transfer of Pellet (x)	3,6	4,2	16,7% incr.	0,0510
Associated Reactions	19,3	20,5	6,2% incr.	0,0510
Deterioration				
Generalisation of Manipulation skills with pellet (gn)	1,5	1,1	26,7% decr.	0,0368
Visual dependence (Manipulation of pellet) (mv)	4,6	2,9	37,0% decr.	0,0020
Dissociation of shoulder elbow wrist (m)	1,7	1,3	23,5% decr.	0,0368
Total manipulation of pellet (excluding mv)	13,6	12,2	10,3% decr.	0,0498
Sum difference of Erhardt items				0,0374

have no awareness of direction of movement in his affected hand at the first assessment but had no problems with proprioception at the final assessment. (See Table 14, Appendix F)

For all the results a ,05 level of significance was used. Parametric methods including T tests were used to analyse scores. Because of the small size of the sample a non-parametric method - the Wilcoxon matched-pairs signed-ranks test was used to check the results. This test is seen as a useful alternative to the T test (Ferguson, 1976). These results confirmed the results achieved by the parametric method for the above four aspects. (See Table 5, P. 91).

Other statistically significant results were areas of significant improvement, and areas of significant deterioration for both the experimental (See Table 6, P 94) and the control (See Table 7, P 95) groups.

Associated reactions decreased and thus improved significantly for both groups. Position of the elbow during approach, transfer of the pellet and stereognosis improved significantly for the control group.

Whereas there was significant improvement in the experimental group in Total manipulation of the pellet (excluding mv), significant deterioration in this area was seen in the control group. Other items in this area that showed significant improvement for the experimental group were Handling of the pellet in the container ($\bar{m}$) and Handling of the pellet excluding pokes thumb. Motivation as judged by the occupational therapist and "Taking off garment" improved significantly for the experimental group. Praxis as judged by the occupational therapist deteriorated significantly for the latter group. Generalisation of manipulation of the pellet and movement (dissociation) of shoulder, elbow and wrist during manipulation of the pellet showed significant deterioration for the control group. Visual dependence during manipulation of the pellet (mv) showed significant deterioration for both groups but more so for the control group.

Further detailed results of each item for every child before and after the experimental period can be seen in Appendix F on Tables 8 to 21 (p 154 - 167).

CHAPTER 5 DISCUSSION OF RESULTS

1. Assessment Procedure

Although precise and comprehensive assessment of the cerebral palsied child is important to enable precise treatment planning and execution, the time used for the assessment has to be kept within realistic limits. To a certain extent each treatment session consists of assessment. The therapist needs to be continually aware of tone changes as well as the quality of automatic and voluntary activity of the components of movement of the child. A baseline of assessment, however, is needed to plan an effective treatment regime and to be able to determine whether progress has been achieved by treatment.

The assessment used in this study took an average of 45 minutes to complete with each child. In retrospect, more detail in certain aspects which may have brought the time to one hour would have been more beneficial. Some items were found not to be useful enough and therefore could be omitted for example, visual attention to objects.

Even though a procedure of assessment was formulated and every attempt was made to adhere as closely as possible to it, fine grading of function was not always easy to judge. This was especially true of the Erhardt part of the assessment. Whether a pattern is partly integrated or fully integrated and whether a pattern is partly integrated or replaced was sometimes difficult to decide.

Although three of the children in the study were diplegics, they had more involvement of one upper limb. The term 'affected upper limb' will be used for the more involved upper limb in all cases for greater clarity in discussion.

1.1. Assessment related to normalisation of tone

Hand-function is dependent on the tone of the whole of the rest of the body. One of the children in the study, R.E., had a dramatic improvement in hand-function (several months before the study was started) after a Tendon Achilles lengthening was performed.

Increased tone in the ankle will affect the position of the pelvis, trunk, shoulder and the whole of the upper limb. This makes assessment of tone of the whole body important. However, in both the test-retest reliability assessments there were variations in tone at rest in different parts of the body from one week to the next. There was more consistency with symmetry and associated reactions of the affected hand. (See Figure 6, Appendix D, P144). There was a one point difference in assessment of tone between testers, one in symmetry and 3.5 in associated reactions. Assessment of tone after effortful activity and during spontaneous and structured movement of the child would have been helpful additions. Handling the child after effortful activity will give an indication of how easily increased tone can be inhibited (Rast, 1984b). The awareness of tone changes throughout treatment is essential to keep treatment precise and therapeutic.

1.2. Assessment related to normal postural reactions

The only postural reaction assessed formally was protective extension (See Erhardt-Placing Responses,P.141 Appendix A).
During this assessment other postural reactions were observed but not recorded. It is important to be aware of the automatic reactions of the cerebral palsied child. Difficulties with balance reactions during use of the upper limb will without doubt have a detrimental effect on hand-function of the cerebral palsied child. Before any voluntary movement can be encouraged a substratum of automatic movement needs to be present. The therapist also needs to be aware of the quality of these reactions throughout the treatment of the child so that requirements of the child can be adjusted accordingly.

In the assessment of protective extension the range of possibilities within the category scoring "partly integrated pattern" was found to be too large. The item "Protective Extensor Thrust" (12 month level) reads "sudden movement of head and trunk backward results in immediate extension of elbows and hands placing on surface". (Erhardt, 1982,p54). A child with a slight delay in response will score the same as a child who partly extends elbows and places partly closed hands on the surface. In this study where the response was complete but slightly delayed a score for the integrated pattern was given, but there was still a big range of possible behaviours within the partly integr-ated category.

1.3. <u>Assessment related to more complex movement sequences</u>

<u>Mobility and stability of the scapulae</u>

The general deterioration in all three of these assessments may be due to stricter reassessment by therapists. These aspects need to be assessed more precisely since they are an essential point of focus in the treatment of hand-function. Both active and passive assessment is important but a scale is not enough. A short description would be more accurate. Stability of the scapula on the trunk is very important and should be assessed together with mobility, paying attention to the activity of the various muscle groups. Reciprocal movement did not really give extra information since this depended on the mobility of the scapula on the trunk.

The following six aspects of the assessment were selected from the Erhardt Test (See Appendix A):-

<u>Arms on approach (sitting)</u> provided a good opportunity to assess the directness of approach to an object and the position of the elbow, forearm, wrist and fingers.

Whether the approach was unilateral or bilateral did not seem applicable to children as old as five to nine years. As the candidate was looking mainly at the performance of the affected limb, the child was encouraged to use that limb for reaching.

The item "one hand grasps, the other may join" (at five months) was assumed to have been replaced in a child who could grasp.

The item "voluntary supination to facilitate grasp" was scored as present when the child supinated more than the midposition in grasping the dowel.

More functional information could be gained in this section by including the child's performance as he reaches for the dowel to different positions and by observing his ability to change direction as he reaches. It would also be important to include how much he needs to compensate for insufficient shoulder movement by using his trunk (Rast, 1984b).

Position of elbow, forearm, wrist and hand

There are various reasons for the assessment of the position of joints of the upper limb during function.

1) Increased tone may make full extension of a joint difficult or impossible. In severe cases there may even be limitation of movement.
2) Selective movement of joints may be difficult or impossible so that movement tends to be in mass patterns, for example, flexion.
3) There may be a retained need to use the tenodesis action of the wrist to open or close the hand.
4) There may be a lack of stability of the upper limb which will affect efficiency of movement of the rest of the arm.

It is, therefore, not enough to note the position of the joint without also noting the above factors. It is also important to specify the initial position of the joint in reaching, grasp or release.

Grasp

In the test-retest situation (See Figure 5, Appendix D,p 143) R.L. was able to do a scissors grasp the second time which was not seen at the first assessment. There also appeared to be traces of the primitive squeeze grasp on the first assessment with the cube which was not seen at the second assessment. There was also a difference of intertester reliability where one grasp was on the border of a palmar and radial palmar grasp (See Figure 3,Appendix C, p 139).

Erhardt's assessment is useful because of the specific illustrations and age levels that help to make assessment relatively accurate.

Hohlstein (1982), however, points out that many well thought of assessments of hand-function amongst others the EDPA, use specific types of grasp against a specific developmental age. Since she found only 34% consistency of using the same grasp in her study of normal infants she believes that this may be misleading and inaccurate. The infants in her study were 65% consistent when the developmental phase of grasp (See P.27) was assessed. In addition to observation of the thumb and wrist as included in Erhardt (during grasp), it is important to observe the involvement of the forearm, elbow and shoulder (including the glenohumeral joint and the scapula on the trunk) as well as the trunk, while the child grasps and releases in various positions, as suggested by Mohr,(1983) and Rast,(1984b). Attention should not only be paid to the type of grasp but also to the child's ability to adjust the pressure of his hand as he grasps the object. The child's ability to stabilize his upper limb without abnormal fixation should also be noted.

The use of Hohlstein's broader developmental phases of grasp with more description of the above aspects as the child grasps and releases in various positions, may be useful in assessment of these skills. The additional aspects of grasp brought in by Loria (1980) when analysing the efficiency of grasp could be useful. She included the aim of the thumb during the approach as well as the angle of the thumb when ready to grasp the object; whether the fingers reached the cube in synchrony; the accuracy of the grasp; the spread of the fingers on the cube; the type of grasp; the number of contacts before securing the cube and whether a tremor was seen or not.

Manipulation

The types of manipulation used with the cube and pellet are simple representative skills which give a good indication of manipulative abilities. Again it is important to note what happens to the rest of the limb as poor manipulation skills need to be corrected more proximally.

In the Test-retest reliability assessment (See Figure 5, Appendix D, P.143) there were several items that varied from one assessment to the next, for example, throwing of the cube, ability to invert the container, use of the thumb to poke, dependence on vision and movement of shoulder, elbow and wrist during manipulation. The therapists agreed on all scores in manipulation except on the bilateral manipulation of the box where there was a slight difference of interpretation (See Figure 3, Appendix C, P. 139). The aspects of manipulation that improved significantly more in the Experimental group will be discussed in Section 2, (P. 108).

There was very little dependence on vision noted when manipulating the cube but more was seen during manipulation of the pellet. All visual skills deteriorated in both groups. This may point to stricter judgement of items at the second assessment and the presence of any of the factors mentioned below. A decrease in visual dependence as seen with the cube and the pellet would be expected to correlate with improved proprioception and stereognosis. However, in the experimental group increased visual dependence was noted with A.D., L.S. and D.D. in spite of improvement in proprioceptive awareness, and in A.D., J.W. and I.M. in spite of improved stereognosis. In the control group increased visual dependence is seen with the four children who improved in stereognosis (C.J., S.T., F.S. and B.J.).

In judging visual dependence a more objective measure is therefore important. In the Erhardt assessment this is assessed with objects, so increased visual dependence may even indicate improved eyehand coordination. The real significance of visual dependence is when vision is necessary in order to move the hand or arm with some accuracy. This happens when proprioception is poor. In children with learning problems this can be seen most clearly in bilateral thumb-finger touching and, for example, in the bilateral drawing of large circles on a blackboard.

In the cerebral palsied child this type of assessment will be heavily influenced by abnormal movement, and is therefore not advisable. In children with abnormal movement the child will at times be encouraged to watch his hand (as more normal patterns are achieved) to augment the feedback of correct movement. Increased visual dependence at this stage will, therefore, be a positive rather than a negative result. The child who has reached more normal patterns of movement could be assessed in the same way as the child with learning problems mentioned above. However, the items of visual dependence should rather be omitted from this assessment and be replaced by noting eye hand co ordination during manipulation of the cube and pellet (except for very young children).

Dissociation of the shoulder, elbow and wrist during manipulation of the pellet is valuable to help determine the function of the arm as a whole.

Generalisation of skills Although this is a subjective judgement made from the child's handling of the object it needs to be included in assessment. There was no change between the two assessments of either of the children in the test-retest assessment and no difference between the examiners. It is, however, not so easy to observe generalisation in such a structured assessment. Observation during free play or during activities in class may be more reliable.

"Awareness of the object" is no longer relevant for children of this age and could be omitted. Selecting a few of the manipulative skills suggested by Elliott and Connolly (See P. 30) could be a useful addition to the assessment of hand-function.

Release and Transfer

As with grasp of the pellet again the child's performance varies within his present capabilities. Each child should, therefore, be given at least four chances and then his best attempt and general strategy should be noted and described if necessary. On the test-retest assessment, (See Figure 5, Appendix D, p.143) performance seemed to depend on the care taken to perform the task and to a certain extent on luck. There were differences in release and in transfer from one week to the next. There was only one difference of judgement in this area between therapists (See Figure 3, Appendix C, P. 139). This was of a transfer.

Grasp, manipulation and release in the Erhardt assessment are all done in one position only. How the child manages skills at different levels - horizontal and vertical - can help to give a better starting point for treatment. This could also help to achieve more exact grading. The child may be encouraged to do the activity where he can do it most normally and this can be graded to include more and more areas (Mohr, 1983). The rest of the body, especially the trunk and proximal part of the upper limb, are not considered sufficiently in the Erhardt assessment. How the child stabilises and whether he needs to fix in abnormal ways need to be included. (Rast, 1984b). The child may be able to do a pincer grasp with abnormal posturing of the rest of the body. How the child manages these skills is therefore just as important as whether he is able to do them.

Although the Erhardt assessment is mainly based on the normal development of handfunction over the first 15 months, the parts chosen could be used with benefit for this group of five to almost eight year old children. Some patterns, however, are not applicable for older children, e.g. 'one hand grasps the other may join' p 133 and should rather be left out for this age group.

1.4. Additional items of assessment

Basic information

The basic information at the top of the assessment sheet is important for any child treated. The "teacher's judgement of intelligence" can be omitted. It was needed to help to group the children since IQ tests had not all been done recently enough.

It is important for the Occupational Therapist to have a little more detail about intelligence and other psychological testing as well as results of perceptual testing. This is especially needed for planning activities at the right level. A short medical history of the child is essential.

The child's motivation, distractability and possible dyspraxia should be included in results of perceptual testing.

Functional Assessment

The only item used for a functional assessment in this study was taking off the garment of the child. To save time and keep this natural for the child he/she was requested to take off whatever outer garment he/she wore above the waist. This could be a pullover, jacket, shirt, T shirt and/or vest. There was one difference on the test-retest assessment (see Figure 6 Appendix D, P 144). KF had his thumb inside his palm the first time and out part of the time at the second assessment.

This item was found useful to show up aspects of abnormal use of the affected upper limb. It would however be more useful to assess his method of dressing and undressing completely so that the therapist can determine adjustments needed and methods to be used to make this daily task as therapeutic as possible for the child. The analysis of dressing by Blacha would be useful here.

During assessment of the child's method it is also important to include the initial posture of the child, his ability to do the postural adjustments needed, his ability to orientate his clothes and to judge where and when to move his body and limbs to dress himself successfully (Rast, 1984b). He may be unable to do parts of it at all or just be able to do them in abnormal patterns of movement or by some or other compensation. It is therefore important to identify components that may need to be worked on separately in preparation for more normal independent dressing. In the meantime the child may need help to do what he already does in a more therapeutic way.

The teacher's judgement of ability to do handwork and drawing helped to give additional information about possible carry over of function gained in treatment. Although the experimental group did better in all three of these items there was no correlation when looking at the results for specific children. Although the teacher's and parent's observations of carry over into daily activities are very important, assessment on a scale is very subjective and too general. More detailed discussion and observation of the exact methods children use (for example to accomplish tasks in class) and to work out whether these are the most therapeutic methods for each specific child would be a better starting point. Assessment of carryover from treatment could then be more specific.

Eye Movements

This assessment was not specific enough. Since the rubber on the pencil was not interesting enough for all children the little animal on the pencil should have been used for everyone. Eye movements were not consistent. This seemed to depend on external circumstances. It therefore seems important to do this assessment on more than one occasion and at different times of the day to get a more reliable result. This discrepancy was seen both with pursuit and convergence. It should be noted whether the child tends to follow or lead the stimulus since this follows in developmental sequence.

Proprioception

This assessment was effective and quick. Two children had difficulty understanding the concept of up and down. There was no difference in the test-retest and intertester reliability scores. This is an important factor to include in assessment. In addition it may be of value to place the affected upper limb in various positions to be copied by the sound limb. (Rast, 1984 b) This will need to be recorded by description or else on a rating scale. This however still only gives information about statesthesia.

It is difficult to assess kinesthesia where there are abnormal movements. A possible way in which the perception of active movement could be assessed could be as follows. The therapist in treatment could teach the child a good movement pattern once tone had been normalised. The child would then be expected to replicate this movement. This would not be easy to do in a standardised way but could provide valuable information for further planning of treatment.

Stereognosis very often determines to what extent a hand is used in function and this must therefore be assessed. There was one difference with each child on the test-retest assessment but no difference on intertester reliability scores. Since stereognosis is heavily dependent on the ability to manipulate an object, (Rast, 1984 b) manipulation needs to be compensated for where necessary.

The child could be given the opportunity to grasp and regrasp the object and to describe, name or demonstrate properties he is aware of for example temperature, general shape, consistency and texture, while comparing it with the given objects open to his view. Duplicate items as used in this study can also compensate for language or memory difficulties a child may have.

It was effective to test the better hand first so that there would be less effect of conceptual difficulties and some familiarity with the objects before assessing the affected hand.

For both the above sections a file to occlude vision was effective and is recommended.

2. Aspects of Significant Improvement of the Experimental In Comparison with the Control group

The aspects of handling the pellet in the container (See P. 92, Table 5, P. 91 and Table 18, Appendix F) that improved most significantly for the experimental group as compared to the control group were "poking of the thumb" and 'poking' of the index finger.

Poking of the thumb will not be discussed (See P. 92,93).

The improvement in 'poking' with the index finger actually meant better differentiation of the fingers. The experimental group also deteriorated less than the control group in dissociation of shoulder, elbow and wrist during manipulation of the pellet (See Table 10, Appendix F). In addition associated reactions decreased significantly for both groups but a little more so for the experimental group (See Table 8, Appendix F.).

These results were not confirmed by improvement in grasp (See Table 17, Appendix F), transfer (See Table 20, Appendix F), or release (See Table 21, Appendix F).

There was, however, a more direct relationship with the results of proprioception (See Table 14, Appendix F). Due to S.M.'s questionable results (See P. 93) the significance of the better improvement of proprioception may be doubtful. In spite of this factor discussion of this area seems profitable since even without her results, there was a strong trend towards better improvement for the experimental group.

Poking activities of the thumb and fingers, like finger painting and printing, used to improve selective finger movements may also have contributed towards improved proprioception. Rast (1984b) suggested some type of poking activity to prepare proprioceptively for grasp.

Three of the five children who improved in proprioception (A.D., L.S. and N.J.) also improved in "hand pokes with .... other fingers flexed". This meant that more differentiation of the fingers was possible. The other two children (R.F. and D.D.) remained the same in this area. The only other two children who improved in this area, S.M. and J.G. of the control group, had top scores for proprioception both times (if S.M. was given the benefit of the doubt in her second assessment of proprioception).

Improved proprioception will imply improved feedback and if the child has the opportunity to experience more normal patterns of movement to benefit from better feedback, carry over of improvement could be expected in activities of daily living.

The significant improvement of "Taking off Garment" for the experimental group compared to no improvement in the control group may be tied to improvement of proprioception. Most of the children who had improved either had a top score in proprioception initially (C.R., R.E., S.M., B.J.) or also improved in proprioception (L.S. and R.F.). The child with the most significant improvement in proprioception, D.D., however, remained the same in taking off his garment. In general however, the retest results of both D.D. in the experimental and C.P. in the control group (who were both operated at the same time) deteriorated substantially. (Some weeks later the functioning in both children improved again).

The overall results of the experimental group were better than those of the control group in the teacher's judgement of the ability to 'Do handwork' and to 'Draw'. The above carry over was, however, not substantiated for the individual children. The same was true for generalisation of skill with the pellet.

No relationship of proprioception was seen with "Stereognosis", the only other sensory assessment included, (See Table 14, Appendix F) or with ability to grasp and release. However, three of the children who improved in proprioception also improved in throwing of the cube. (A.D., L.S. and R.F.) and the other two remained the same (D.D. and N.J.) (See Table 21, Appendix F).

Correct feedback of movement patterns seems to be one of the most important factors in the treatment of cerebral palsied children. The therapist therefore also needs to make us of the other two mechanisms of feedback mentioned by Bossom (1974). (See P. 9)

1. Corollary discharge - The reason why children do progress in treatment in spite of poor proprioceptive awareness is probably mainly due to the role of corollary discharge which only operates when movement is active (Jones, 1974). Because the child learns from his/her movement in this way, all movement the child does in therapy has to be as normal as possible. This means movement with normalised tone, and with a minimum of effort, in 'normal' patterns, with the attention of the child on the activity rather than on the movement.
2. Sensory input from the external world - Direct visual and auditory feedback to the child by the therapist as she is working with the child (Blacha, 1983b) is very important to supplement the corollary discharge. The therapist can let the child know directly by her face and voice when movements are correct and when not. Visual cues

for the child could also help the child to monitor voluntary movement (Jones, 1974). He could, for example, get the cue for correct positioning from the normal hand as it is used together with the affected hand. In all the studies where augmented biofeedback was used with visual and/or auditory signals, single muscles were stimulated. Because the therapist does not work with single muscles but with movement patterns in the cerebral palsied child, this method is not so helpful in treatment. There may, however, be possibilities of development in this area in future.

Augmentation could also be provided by success in an activity that is carefully structured to elicit correct movement. The goals of the activity should be set accurately, and the child should be able to observe the successful performance of the activity.

Moving a magnetised counter along until it clicks into place while playing a simple table game positioned to elicit the exact movements required could be an example. In some cases use could perhaps be made of therapeutic apparatus where the correct movements will elicit the desired reaction of the motivating apparatus. The therapist is, however, treating the whole child and has to keep in mind normal development and the diverse movement needs of every human being.

In the normal child many aspects develop simultaneously and are then brought together, and the occupational therapist must bear this in mind.

Erhardt's method of choosing specific activities for the child follows the above rationale. One of her examples is stapling papers together in a specific way. As the child repeats this activity in the prescribed position with the specific goal in mind, this particular movement pattern can be perfected. At a later stage it can possibly be incorporated into other specific activities. As more and more 'normal' patterns are learned the child has a larger repertoire of 'correct' movement patterns. Initially with, and then without the help of the therapist he can begin to combine, modify and recombine movement patterns to include many other daily activities.

3. The Possible Contribution of Various Aspects of Treatment

3.1. Normalisation of tone and

3.2. Facilitation of normal postural reactions

Although tone was improved during each session, the therapist was not aware enough of fine variations in tone especially in reaction to each component of movement. This was subsequently very carefully demonstrated by Blacha (1983) based on the work of the Bobaths, Bly and others.

Active automatic reactions were elicited from the child but the grading could have been more exact. The therapist was not sufficiently aware of what was already automatic for the child so she could not build on this carefully enough.

Tone was therefore not inhibited optimally and the normal postural reactions were not graded exactly enough.

Of the three aspects reflecting tone, associated reactions decreased significantly for both groups but less so for the control group. The improvement as shown by the reduction in the amount of associated reactions in the affected upper limb may be due to the emphasis in treatment on weightbearing on this limb. The same may be true of the children in the control group since the children S.T. and E.J. who showed the biggest improvement in this area had weightbearing included as a substantial part of their treatment.

Although symmetry which is also a reflection of tone, improved for the experimental group and deteriorated for the control group, the improvement of tone at rest was less for the experimental group than for the control group.

In later sessions a few of the children tended to want to hurry this part of the treatment as they were looking forward to the more interesting activities following. The attention and involvement of the child could possibly be maintained by having objects against the wall or suspended from the ceiling. These objects could be involved in an activity which would require automatic adjustments of posture at the right time. This should not compromise the quality of automatic reactions, but could be used when grading to automatic reactions with a voluntary component.

During treatment, tone control by weightbearing on the affected upper limb, had a direct effect on the hand. Although positioning of the whole body and bringing in components of rotation helped to control tone in the final parts of the session the starting positions were not always stable enough. Better results were obtained in the more stable positions like sitting on a block or chair of the correct height. Rast (1984b) pointed out, however, that too much abduction of the lower limbs, e.g. sitting astride a wider block, may block movement of the lower trunk. Children tended to prefer and also perform better if the main working surface, preferably a small table, was in front of them. An additional surface to either side vertical, horizontal or at a slant and carefully placed as to height and relationship to the child, was found to be helpful in the achievement of the therapeutic aims.

Printing on the wall at shoulder level on the child's unaffected side was performed with better alignment and movement by most children than printing in front. More "hands on" control, especially of the pelvis and shoulder girdle, could have helped to achieve more optimal patterns of manipulation, grasp and release. This more normal tone could also have helped to give more exact proprioceptive feedback. The only item related to postural adjustment 'Protective extension' showed a slight and equal improvement for both groups.

3.3. Facilitation to obtain more complex movement sequences

Some type of weightbearing was included in every session in order to prepare the hand for more efficient function later in the session. Weightbearing on different textures was effective during treatment. Carry over was, however, not marked since similar improvement in stereognosis was seen in both the experimental and the control group. This may, however, have had a beneficial effect on proprioception of the upper limb. Alternate weightbearing with one hand while actively using the other hand (together with rotation in the trunk) particularly had a good direct carry over to more efficient hand-function. Walking on the hands was found good but the therapist had more control of alignment when the child was walking over a ball or a roll rather than when he was only held by the therapist. Taking weight against a wall was not as effective since it was difficult to get the correct weight distribution and movement over the hand. Taking weight on both hands astride a roll while lifting the seat as the roll was moved by the therapist provided for most children good weightbearing in good alignment of arms and hands. More direct 'hands on' control of the scapulae would, however, have improved the effectiveness of this activity. Sidesitting was not found to supply enough 'mobile' weightbearing except when used with a gross motor acitivity like throwing a ball at skittles with one hand while taking full weight on the other hand and alternating to the other side.

The play activities were enjoyed by all the children and this encouraged them to repeat the movement patterns required by each activity. Although the best results of treatment of cerebral palsied children can be expected at an earlier age, children of this age (five to eight years), can be requested to do an activity in a specific way and they can still have fun doing the activity. For a younger child activities mostly have to be structured so that only the required movement will make it work (e.g. a mechanical or electronic toy).

The simplest activities achieved the best results. As soon as the activity became more complex more effort tended to be required by the child. In addition, the therapist could not control the movements well enough since more attention needed to be paid to the activity.

Weightbearing has probably had the greatest contribution to the areas of significant improvement. However, the alignment of the arm could at times have been more exact. Weightbearing on the various parts, especially the thenar eminence, could also have been more precise and more carefully graded. Above all preparation of the shoulder should have received more specific attention (See Section 4, P. 120). The fact that involvement of the hand in treatment mostly consisted of manipulating activities, appears to have been one of the biggest reasons for the significant improvement in the area of manipulation of the pellet. Activities like printing or painting with the fingers brought the best individual movements and simple folding and smoothing activities (for example, after pasting) provided the best whole hand activities.

The principles of learning movement patterns confirms how important it is to give the child the opportunity to use the more normal movement gained by the inhibition of tone and facilitation of movement. It appears to help the child to preprogram simple movement sequences. The activities need therefore to be similar enough to present the same movement aims until these movements are perfected and yet sufficiently different to keep the interest of the child. The child needs to be helped to generalise to different situations.

Activities that could not be structured exactly enough tended to elicit abnormal movement. Handling a finger puppet, rolling of clay and playing in the sand in various ways tended to bring out abnormal patterns in the child's affected hand. Specific movement could not really be expected in these activities. Movement required needs to be very specifically built into the activity.

An activity used in treatment should not have too many goals or too many treatment requirements. Ideally a small part of a movement accomplishing a simple goal needs to be perfected before an additional movement requirement can be added.

The improvement in manipulation was not carried over to grasp nor to transfer or release of the pellet where improvement was better in the control group. Since these are developmentally more advanced skills this may not be surprising. When grasp was used in treatment static grasp was avoided.

Some activities first thought to contain enough mobility, like tearing paper and threading large beads were found to be too static for most children. The child would do all the movement with the better hand and keep the affected hand statically holding on to the object. Since the static hand was not in a good position with the above activities, associated reactions tended to reinforce the abnormal positions. Objects that encouraged a 'good' posture of the hand were used mainly. Hyperextension of the metacarpophalangeal joints were, for example, avoided by the shape of the objects chosen. Cylindrical or spherical objects of the right size or larger flat objects were found to be best.

One of the reasons causing hyperextension of the metacarpophalangeal joint of the thumb, is shortening of the muscles of the first interosseus space, drawing the first metacarpal closer to the second metacarpal (Kapandji, 1970). Elongation of these muscles would therefore be important before expecting functional movement.

In the study, treatment was only done together with and by the use of activity. However, as Rast (1984b) demonstrated, activity can be used more meaningfully and with better results after some direct preparation of the child. She used elongation of muscles and compression of the joint in a well aligned position, followed by tactile stimulation, weightbearing and weightshifting over the joint. Preparation of the upper limb in this way could have been done with benefit for all the children.

<u>Associated reactions</u> seemed to be N.J.'s biggest problem. This gave the appearance of very clumsy hand-function although she had relatively good, controlled movement with both hands. The hemiplegic child, due to abnormal tone and abnormal feedback may have had insufficient experience of normal movement on the affected side. The affected side will therefore normally move in an abnormal way or the child will use the normal side to perform the function with resultant associated reactions which increase the tone and abnormal feedback through the affected side.

Treatment involved weightbearing followed by voluntary control of the more affected hand. She was at this stage, for example, asked to place the affected hand on an outline on the table and to keep it there while involved in activity of the other hand. This resulted in definite progress in the inhibition of associated reactions and carried over to improved selective movement of her fingers.

A hemiplegic child has to a greater or lesser extent learned correct patterns of movement on the normal side. The 'feeling' of these movements may help to reinforce correct patterns of movement on the more affected side. This is seen, for example, when doing symmetrical bilateral movement. In treatment of the children in the study symmetrical bilateral activities tended to carry over good movement of the better hand to the affected hand. Playing blow football holding a detergent bottle in both hands produced a good movement. This was done astride a roll with the goal towards the side. The squeezing action and the excitement tended to raise the tone of some children, but in spite of this the effect was good.

The grading of bilateral activities used by Rast (1984) in the treatment of, for example, a hemiplegic child, could be followed with profit. Her suggested sequence was:-

1) Weightbearing on both hands, for example pushing a large ball with both hands, protective extension or weightbearing over a roll.
2) Holding an object with both hands - for example holding a bucket in both open hands, holding a dowel and moving it from the shoulders, holding a small hoop and turning it around and back without letting go. (Small hoops and different coloured dowels can be used in many different ways.)
3) One hand holding, the other moving - for example holding a tube and dropping objects inside, holding a jug and pouring in seeds or water or washing a therapy ball while stabilising it with one hand.
4) Two hands reciprocally holding and letting go - for example climbing a rope ladder. Pushing a small smooth ball through a cloth stocking by alternately placing flat hands on the stocking on a table or by pushing the ball through squeezing with alternate hands. Walking with hands along a hoop being twisted and turned slowly by the therapist can also be used.
5) Both hands active differently but to a similar degree, for example washing and drying hands, wrapping something in a towel or paper folding activities.

The holding of an object with the affected hand while using the other hand was kept to a minimum in this study except in short part-activities like opening and closing a glue bottle. Considering this sequence, tearing of paper, was too advanced for most children in this study. Grading in this area should have been more exact throughout the study. If Loria and Blacha are right in saying that there is a separate more cortical system especially concerned with the thumb and index finger, cortical involvement would be particularly important in treatment of this aspect of hand-function.

Voluntary movement elicited by an activity involves the child's attention and his intention. To get smooth movement the child has to know what he is doing now and has to be able to anticipate what he will be doing next. However, even thinking of a remembered movement, for example, stirring soup, may bring back the whole abnormal pattern used when doing this previously (Rast, 1984b). The border between voluntary movement bringing on an abnormal pattern and normal" voluntary movement is therefore very narrow and very important to determine in treatment. On the whole a more normal movement is elicited if it can be done through a very specific requirement of an activity.

Sometimes a movement needs to be achieved with the help of the therapist and consciously experienced before an activity can be brought in (Rast, 1984b). It is, however, important to allow the child to use each new 'normal' movement pattern he manages to do in one or other functional activity.

It must be remembered that improved function occurs in perfecting the solution of a problem - rather than practising a stereotyped movement (Connolly, 1975).

Campbell et al (1984) used this principle successfully with severely involved children with cerebral palsy. The therapist would choose a target behaviour, for example reaching to the midline. She would then identify potentially motivating activities for the specific child to give him a reason for accomplishing the target behaviour. All who came in contact with the child were taught the correct inhibition and facilitation techniques to use for the specific child to help him accomplish the movement correctly.

Because this specific movement was used to achieve many different goals important for the child, it was assumed that it would be more likely to be generalised as part of the child's everyday behaviour. Both the child's overall performance and the rate of acceleration of responding correctly were better with activities they preferred. Quality of improvement, however, also depended on the effectiveness of the inhibition and facilitation (the guidance) of the movement.

Michael (1984) found that videotapes of specific handling techniques that could be followed by the parent and teacher in some cases were much more effective than any other type of instruction. Von Wendt et al (1984), however, pointed out (based on other author's observations) that it was important to prevent parent involvement in treatment goals from cutting down the mother's personal care of the child. This could delay the social maturation of the child.

4. <u>Aspects of Treatment that were not emphasized sufficiently</u>

The areas of the Erhardt assessment where the experimental group improved less than the control group were position of the elbow and hand during approach, position of the wrist during release of the pellet, grasp, transfer and release of the pellet and transfer of the cube. (See Figure 1, P.89). The areas of the additional items that were below that of the control group were praxis as judged by the occupational therapist of each child, mobility in the glenohumeral joint, reciprocal movement of the scapulae and tone at rest.

With inadequate scapulo-humeral function one can expect less stability of the joints of the upper limb as well as insufficient coordination, as would be seen in grasp and release, including transfer. Tone would affect all movement as was discussed on P. 112 and 113. Judgement of praxis may be influenced by the co-ordination of movement.

Treatment to improve mobility of the scapula on the trunk as well as glenohumeral movement was mostly done together with weightbearing in various positions; with activities of release, where shoulder movement was encouraged and in activities of large movement of the shoulders while holding onto an object for example a towel. Attention was also paid to reciprocal movement. However, treatment did not distinguish sufficiently between movement of the scapula on the trunk and movement of the glenohumeral joint. In addition insufficient attention was paid to stability of the scapula on the trunk.

Eliciting voluntary movement from the child does not appear to be sufficient in the treatment of the shoulder girdle or in achievement of stability in the upper limb. 'Hands on' preparation of the child is thus essential to achieve more precise control of function.

Blacha's method (1983b) of using alternate traction and approximation with the child in prone and his arms elevated to mobilise the scapulae on the trunk, can be effective. (Traction is used to inhibit and approximation to stimulate active muscle work.) Scapular stability needs to be achieved first with weightbearing on elbows, then with straight arm weightbearing and weightshifting with the scapulae in various positions of adduction to abduction.

Weightbearing on one side and shifting weight onto this side without losing control while reaching out with the other hand and maintaining the stability of both scapulae needs to be worked on.

Traction-approximation can also be used to encourage dissociation between the scapula and the humerus, for the elbow joint with special attention to tight pronators and the wrist joint as needed. This needs to be continued to the webspace of the thumb with special attention to the carpometacarpal joint including each of the other thumb joints and each of the other finger joints. Care must be taken not to push any joint into abnormal positions like hyperextension. The longitudinal palmar arch of the hand may also be mobilised if there is tightness between the metacarpals (Rast, 1984b).

Tactile preparation of the hand by, for instance, sweeping the hand through lentils, against a surface, on clothes or against a carpet can be useful (Rast, 1984b).

The child has to learn to bear weight on the upper limb and shift weight over this limb as more mobility of the glenohumeral joint with dissociation from scapular movement is gained. (Weightbearing on various surfaces gives good tactile input to the hand). This needs to be followed by placing of the upper limb into various positions with special attention to stability of the scapula on the trunk. Placing of the limb needs to include external rotation, flexion and horizontal adduction as dissociation becomes more complete (Blacha, 1983b). Placing and reaching by the upper limb may be elicited by asking the child to pop a soap bubble held by another person, disturbing a ball or car on the top of an incline to set it going or touching a switch to start a toy (Rast, 1984b).

Only after this can swiping of, for example, soap bubbles or a ball be brought in.

The other factor which deteriorated significantly in both groups, although less so with the experimental group, is dependence on vision during manipulation of the pellet. Although visual dependence should not be encouraged, eye hand co-ordination is frequently deficient in the cerebral palsied child.

Because this is of such importance to hand-function, special attention needs to be paid to vision and visual skills when working on improvement of function of the hand.

The possibility that vision is an anticipatory system for grasp (Bower et al, 1970) may remain a factor as the child becomes older even though the child becomes less visually dependent.

As the child's first eye-hand co-ordination develops from swiping at an object, slow swiping where an object is touched but not grasped could be used to combine working an eye-hand co-ordination as well as shoulder stability.

A sturdy surface that can be fixed at various angles and wheeled to any position before being locked into place, could be helpful. Objects could be, for example, magnetic on a metal board, or felt on a felt board. The various boards could be clamped onto the surface.

Initially the activity will be gross motor but from the beginning a visual stimulus should be involved. This helps to structure the movement for the patient. Careful positioning of the stimulus will be important to fulfil other neurodevelopmental needs discussed above. Visual attention to the target and indirectly to the upper limb could also augment the feedback of 'normal' patterns of movement that need to be reinforced.

In Sensory Integration Therapy the postural occular system is seen as a whole and eye movements are improved by developing postural mechanisms with the emphasis on improvement of neck extensors. (Ayres, 1972).

In the cerebral palsied child eye movements may also need to be considered as part of the postural occular system. Investigation is needed into specific ways of improvement of eye control and eye movements in the cerebral palsied child.

The most important areas that were not sufficiently emphasized in treatment of the children in the study were differentiation of the scapula on the trunk and the scapulo-humeral joint; and the achievement of stability in the various joints of the upper limb. These factors are essential for the achievement of improved hand function.

CHAPTER 6 CONCLUSION

In conclusion, the hypothesis that spastic cerebral palsied children treated by the use of play activity in a programme specifically designed to improve hand-function will improve more than children who are treated without the emphasis on improving hand-function, may be accepted. There was a trend towards better improvement and less deterioration in favour of the experimental group.

Although on the whole only marginal improvement in hand-function was seen in this study, it is possible that with a change of emphasis or certain modifications, as suggested, more convincing results could be obtained.

The purpose of the study (See p. 3) was accomplished as follows:-

- By making use of a study of literature significant factors involved in the normal development of hand-function were identified and discussed.
- In the same manner factors contributing to the abnormal development of hand-function in the spastic cerebral palsied child were pointed out and discussed.
- A method of assesing hand-function was adapted, making use of parts of the Erhardt Developmental Prehension Assessment and additional items. This was used in pre- and post-assessment of all the children and evaluated thereafter.
- Certain methods contributing towards improvement of hand-function through the medium of play activity were used to treat the children in the experimental group. These methods were evaluated and changes and additions were suggested to achieve more efficient hand-function.

The most vital concept arising from this study is the importance for the occupational therapist to work consciously and systematically towards the improvement of specific hand-function. Bobath and Bobath have recently (1983) underlined the fact that carry over of movement patterns achieved in treatment does not occur spontaneously. Treatment has to include various positions of function and changing from one position to the next. Inhibition and facilitation to achieve 'normal' movement patterns needs to take place in the various functional situations of the specific child.

Keeping this in mind the occupational therapist needs to use appropriate methods for the child to achieve optimal hand-function during the various activities engaged in by the child.

Play activities can be structured exactly to achieve specific therapeutic aims. In addition, if presented appropriately they can be enjoyable and in themselves encourage the child to repeat required movement patterns started during a treatment session and continued in the child's own time.

CHAPTER 7 RECOMMENDATIONS

Recommendations are given for improved assessment and treatment.

Assessment

1. A hand-function assessment, including the analysis of components of movement during specific reach, grasp, manipulation and release of objects by the hand, needs to be designed. The following suggested alterations or additions to the assessment used may be helpful towards this goal.
2. Tone should also be observed during activity, including strenuous activity like jumping. It should also be noted how soon excess tone is reduced after strenuous activity.
3. Proprioception should also be assessed by placing the affected limb in a position to be copied by the better side (vision excluded).
4. Special attention should be given to the assessment of the stability of the scapula on the trunk.
5. Dissociation between movement of the scapula on the trunk and movement at the glenohumeral joint should be noted.
6. Posture and movement of the rest of the upper limb and trunk should be noted during grasp and release.
7. Stability of the various joints of the shoulder girdle and upper limb should be assessed. The objects to be grasped and released should also be placed slightly higher than the table top, for example, to observe the stability of the wrist in action.
8. When assessing eye movements:-
   - a pencil puppet should be used to ensure optimal attention of the child;
   - leading or following of the eyes should be noted; and
   - more than one assessment should be done at different times of the day.

Treatment of Hand-function

1. All the aspects of play should be considered during treatment
   - exercise play can, for example, be used during initial normalisation of tone;

- symbolic play - the use of imagination can be brought into almost all aspects of treatment, depending on the age of the child;
- games with rules can be used especially for the older child, at times even bringing in another child, and
- games of construction and problem solving (including play activities as used in the study) can be used well with manipulative activities and grasp and release. Care should, however, be taken to keep this play simple to require exact movement.

2. Simple play activities need to be developed to be used for each aspect of treatment.

3. The occupational therapist needs to have her hands on the child during treatment even though the emphasis in treatment is on functional activity. In this way she can prepare the child for optimal control of movement and maintain normalised tone throughout the session.

4. Normalisation of tone should include neck extensors and flexors; active control of the neck is important so that abnormal fixing by the elevators of the shoulder girdle is no longer necessary.

5. Starting positions need to be stable when bringing in more specific hand activities. Positioning of the child and the activity should be designed to help keep tone normalised. If, for example, rotation or positions at different levels could be of benefit to the child these need to be momentary parts of the activity and should not require too much control.

6. The therapist needs to be aware of what the child can do automatically so that further automatic reactions can be built on those already present. Voluntary activity can then be elicited on the basis of awareness of the underlying automatic movement of the child.

7. Stability and mobility of both the scapula on the trunk, and the scapulo-humeral joint, separately and together, need to be a focus of treatment. 'Hands on' preparation by very specific approximation and traction involving the scapula on the trunk, and later the scapulohumeral joint need to be done. Weightbearing and weightshifting on the limb and placing activities of the arm are important before requiring any specific movement. Dissociation between the scapula on the trunk and the glenohumeral joint is essential.

8. Stability of the elbow, forearm and wrist should receive special attention. This could be done as suggested by Blacha (See p.121).

9. Stability of the metacarpophalangeal joints of the fingers and thumb is essential. Preparation of the joints as suggested by Rast (p.120) may be helpful together with elongation of the muscles of the webspace as needed. In some cases a splint might be necessary to avoid chronic hyperextension during activity. Hyperextension of joints can be avoided by choosing correct shapes and sizes of objects for the child to handle. Cylindrical, spherical or thick flat objects of the right size which are light and firm can be of benefit. Smaller objects should only be brought into treatment after more selective movement has been achieved in manipulating activities and after grasp and release can be done with more normal control of the fingers and thumb (without abnormal postures).

Manually lifting the child's metacarpophalangeal joints and positioning the hand over a large ball or square edge of some kind as suggested by Levitt could also be helpful to maintain the better posture gained by the preparation (Levitt, 1977).

10. Feedback should be kept as 'normal' as possible by keeping tone normalised, by making movements as simple and precise as possible and by augmenting feedback by vision and/or hearing.

11. Sensory input needs to be part of the preparation for treatment. Weightbearing on various textures could lead to improvement of stereognosis and proprioception. Improvement of these should be a priority in treatment.

12. Augmented feedback can be supplied to the child by the design of activities incorporating visual, auditory and/or tactile cues to help create a goal for "normal" movement patterns.

13. Inhibition of associated reactions is important to minimise confusing feedback.

14. Conscious control of overflow of movement should be encouraged where applicable, starting from weightbearing on the limb. After this the hand can rest open on the outline of a hand and the child can be encouraged to keep the hand from moving while involved in activity with the other hand. This then leads to bilateral activities.

15. Bilateral hand-function should be graded carefully (See p.117). If alternate hands are used in an activity, care should be taken to build this into the activity naturally so that the child does not have to think about moving the affected hand.

16. Eye-hand co-ordination needs to be part of the treatment even with reaching and placing activities.

17. Methods of improving the eye movements of cerebral palsied children need to be investigated.

18. Small components of movement need to be practised before they can be combined into more comprehensive movement patterns.

19. The contribution of cortical involvement when working on specific finger movements, especially of the thumb and index finger, needs

to be investigated.

20. Treatment should be structured with the focus on manipulative activities before any grasp is attempted. When using fingers individually, as when printing with the fingers or the thumb, hyperextension of the fingers can be avoided by giving the child a roll of bandage or similar object to hold in the same hand.

21. Activities which elicit specific movement patterns to suit the treatment requirements of each child need to be designed. An example of this is Erhardt's recommendation of the use of a stapler in a prescribed way. Such an activity should be motivating to the child and could then be encouraged outside treatment sessions.

22. Simple daily activities that have meaning for the child can be used to ensure regular practice of a 'normal' component of movement.

23. Methods and adaptations need to be worked out for the child to accomplish daily tasks, even parts of a task, for example, doing part of his dressing in as therapeutic a way as possible so that good movement patterns can be practised during the day. In the same way attention needs to be given to activities in class and even in the playground without hampering his spontaneity in free play.

Above all it is hoped that this study will help to stimulate other occupational therapists to work more specifically to improve the hand-function of spastic cerebral palsied children.

APPENDIX A

HANDFUNCTION STUDY ASSESSMENT

EROS SCHOOL OCCUPATIONAL THERAPY

NAME .... SEX ..... ☐ DIAGNOSIS .... Tri 1, Hemi 2 ☐

SEVERITY: Sev (0) / Mod (1) / Mild (2) ☐ OTHER ILLNESSES .... Yes/No ☐☐

TEACHER'S JUDGEMENT: (0) Dull / (1) B Ave / (2) Ave / (3) Br / (4) VBr ☐ IQ .... ☐ Wasting .. ☐

EXAMINERS .... ASSMNT DATE .... BIRTH DATE .... CA ..... ☐☐☐

CLASS .... TEACHER .... ☐ OT .... ☐ PT ..... ☐ ST ...... ☐

NUMBER OF TREATMENTS PER WEEK .... ☐ .... ☐ .... ☐

KEY: Very poor 0, Poor 1, Fair 2, Good 3, Excellent 4.

1. Child's motivation for treatment .... ☐
2. Distractibility .... ☐
3. Apraxia .... ☐
4. Taking off garment (gm) Position shoulder/position elbow/position wrist/ position fingers/hold down gm/grasp gm/grasp gm c̄ ext wrist/grasp gm c̄ thumb out of palm/grasp c̄ sup. hand. Total ☐
5. Scapular movement - no movement possible 0/def. limited 1/mod. limited 2/ fairly limited 3/no limitation 4.

Scapula on trunk L ☐ R ☐ Dissociation from g/h joint L ☐ R ☐ Reciprocal movement L ☐ R ☐

ASSOCIATED REACTIONS (Supine) Ass. Reactions to aff. arm and hand excessive 0/ sev. 1/mod. 2/mild 3/not present 4.

Lift Head	☐	Elevate u arm	☐
Abduct L leg	☐	Squeeze Ex fingers c̄ u hand	☐
Abduct R leg	☐	Place pellet in C c̄ u hand	☐
Abduct unaff (u) arm	☐	Total	☐

Symmetry: trunk head shoulder elbow wrist hand thumb hip knee ankle foot toes

Total ☐

Tone: Low* (0), Severe (1), Moderate (2), Mild (3), Normal (4).

	L	R
Head & Neck		
Trunk		
Shoulders		
Elbows		
Wrists		
Fingers		
Thumbs		
Hips		
Knees		
Ankles		
Toes		

	L	R
Total		

Eyemovements

(a) pursuit — no fixation possible 0/fixation poor 1/definite midline jerk & jerkiness 2/slightly irregular 3/no problem 4 ☐

(b) convergence - Cannot converge 0/converges slightly 1/converges but looses part way 2/converges but cannot hold 3/ converges and holds for 2 secs. 4. ☐

Proprioception: - distal phalanx held both sides.

eyes open - L middle finger up/down

eyes closed - L ring finger down/down. L index down/up L ☐

R ring finger up/up. R index up/down R ☐ L ☐ R ☐

Stereognosis

Marble (M) Cube (C) · Button (B) Safety pin (S) Reel (R)

Better Hand : M / C / B / S / R Worse Hand : S / C / R / B / M L ☐ R ☐

Time : ☐☐☐☐☐ ☐☐☐☐☐

	L	R
Total time		

* If child scores 0 for low tone, the total of the scores of tone is not meaningful and should not be calculated.

KEY

Action or aspect to observe

$\bar{a}$ - awareness

v - visual

p - position

m - movement/placement

x - both hands/transfer

r - reaches

g - grasp

$\bar{m}$ - manipulation

l - let go (release)

l 1 - against surface

l 2 - above surface

l 3 - into large container

l 4 - into small container

gn - generalisation

Body parts involved

s - shoulder

a - arm

e - elbow

f - forearm

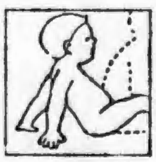
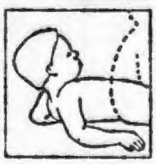
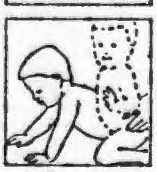
w - wrist

h - hand (fingers)

t - thumb

Developmental Levels | **Pattern Components** | **Placing Responses**

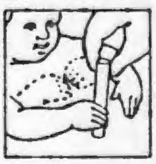
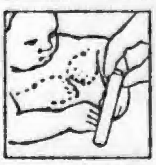
KEY [0] No pattern components present. [1] Some but not all pattern components present. [2] All pattern components present. [3] All pattern components replaced.

Developmental Levels (Left / Right)		L R	
12 months		[ ][ ]	**Protective Extensor Thrust:** sudden movement of head and trunk **backward** results in immediate extension of elbows and hands placing on surface. (2)* m e h
10 months		[ ][ ]	**Protective Extensor Thrust:** sudden movement of head and trunk **backward** results in immediate extension of arms and flexion of elbows placing on surface. (2) m a e
8 months		[ ][ ]	**Protective Extensor Thrust:** sudden movement of head and trunk **sideward** results in immediate extension and abduction of arms and fingers. (2) m a h
6 months		[ ][ ]	**Protective Extensor Thrust:** sudden movement of head and trunk **forward** and **down** results in immediate extension of arms and extension and abduction of fingers. (2) m a h
3 months		[ ][ ]	No protective response to sudden movement of head and trunk **forward** and **down**, arms remain flexed or hypotonic. (3) m a

* Highest possible score

Total m [ ]

The Arms on Approach (Sitting)

Developmental Levels (Left / Right)		Pattern Components (L / R)
12 months		Voluntary supination to facilitate grasp (2) p f
10 months		Wrist extended (2) p w Appropriate finger extension (2) p h
8 months		Unilateral direct approach (2) r Excessive MCP extension (3) p h
6 months		Unilateral circular approach (3) r Elbow fully extended (180°) (2) p e Excessive finger extension (3) p h Wrist straight (3) p w Wrist in midposition between supination and pronation (2) p f
5 months		Bilateral angular approach (3) r x Underreaching, adjusting, then corraling object (3) r Elbows extended 140° (3) p e Hands open (3) p h One hand grasps, other may join (3) g x
4 months		Bilateral backhand approach, ulnar side leading (3) r x Contacting and pushing object only (3) r Elbows extended 100° (3) p e Wrists pronated (3) p f Hands partly open (3) p h
3 months		Unilateral approach to side only, arm abducted (3) r Elbows flexed (3) p e Wrists flexed (3) p w Hands flexed (3) p h
Natal		No approach (3) r

Present dowel (vertically) in midline at arms length.

Observe p e f w h

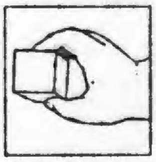
r / r x / g x

	g x	r	r x	p e	p f	p w	p h
Total							

Developmental Levels | **Pattern Components** | **Grasp of the Cube (Supine, Prone, or Sitting)**

Left | Right | **L | R**

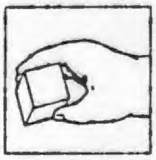
9 months



Radial-Digital Grasp

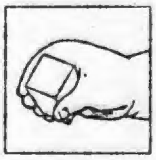
Wrist extended (2) p w

8 months



Radial-Digital Grasp: object held with opposed thumb and fingertips, space visible between (2) g

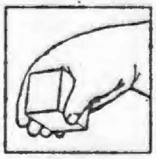
7 months



Radial-Palmar Grasp

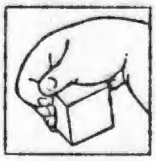
Wrist straight (3) p w

6 months



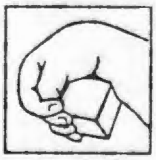
Radial-Palmar Grasp: fingers on far side of object press it against opposed thumb and radial side of palm (3) g

5 months



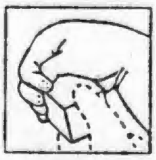
Palmar Grasp: fingers on top surface of object press it into center of palm (3) g
Thumb adducted (3) p t

4 months



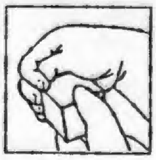
Primitive Squeeze Grasp:
Visually attends to object, approaches if within 1" (3) v
Contact results in hand pulling object back to squeeze precariously against other hand or body, no thumb involvement (3) g

3 months



Visually attends to object, and may swipe, but: (3) v
Sustained voluntary grasp possible upon contact only, ulnar side, no thumb involvement (3) g
Middle finger strongest, followed by ring and little fingers (3) g
Wrist flexed (3) p w

Natal



May visually attend to object, but: (3) v
No voluntary grasp, only reflexive (3) g

Request

1. Grasp block on table.
2. Drop , throw , push , pull .
3. Combine blocks.
4. Manipulate box / shake.
5. Release on surface, in large and small container.

Observe

1+2. g / v / p w h t
3. p h t
4,5,6. m / p w h t

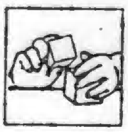
	g	v	p w	p t
Total				

Developmental Levels | Pattern Components | **Manipulation Skills (Prehension Schema)**

Left | Right   L | R   L | R

One hand holds object while other manipulates it (2) m̄ x
Tower of 2 blocks (2) m̄ x

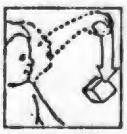
12 months



Combines objects (2) m̄ x
Unsuccessful tower of 2 blocks (3) m̄ x

Active, experimental manipulation within visual field (rotating, squeezing, transferring) replaces mouthing (2) m̄

8 months



Reciprocal Assimilation:
Watches hand to prolong movement, and keeps hand moving to make interesting sight last (3) m̄ v
Movement limited to visual field (3) m̄ v

Hand drops object (2) m̄ 1
Hand throws object (2) m̄ 1
Hand pushes object (2) m̄
Hand pulls object (2) m̄

7 months

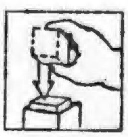
Object Permanence:
Searches for object if removed, ignoring new stimulus (3) ā
Drops object when grasping another (3) ā

Retains object when grasping another (2) ā
Shakes one or both objects, alternating visual monitoring from one to the other (3) m̄ v

Developmental Levels | Pattern Components | **Release of the Dowel or Cube (Supine, Prone, or Sitting)**

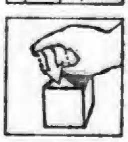
Left | Right   L | R

12 months



Precise, controlled release into small container (2) 1 4
Wrist extended (2) p w

10 months

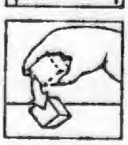


Clumsy release into small container, rests hand on edge (3) 1 4

9 months

Controlled release into large container (2) 1 3
Wrist straight (3) p w

8 months



Clumsy release above surface or into large container (3) 1 3
Unsuccessful release into small container (3) 1 4
Wrist flexed (3) p w

7 months

Assistive release against surface (3) 1 1
Unsuccessful release above surface or into large container (3) 1 2
Adept 1-stage transfer: simultaneous grasp and release (2) x
Supinates to let object fall out (3) 1

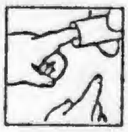
ā	m̄	m̄ 1	m̄ x	m̄ v	x	1	1 1	1 2	1 3	1 4	p w

Developmental Levels | Pattern Components | Manipulation (Sitting)

15 months

Inverts container to reach contents (2) m̄
Manipulation possible without hand and object in same visual field (2) m̄ v

10 months



Hand pokes with index finger, other fingers flexed (2) m̄
Tries to remove object from container by reaching in (2) m̄

9 months

Hand tries to poke, all fingers extended (3) m̄
May use thumb to poke (3) m̄

Skills generalized to new situations (2) gn
Associated (mirror) movements of other hand (3) m x
Shoulder, elbow, and wrist motion (2) m s e w
Grasping occurs only when hand and object are in same visual field (3) m̄ v

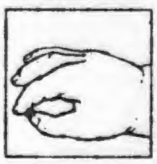
Developmental Levels | **Pattern Components** | **Grasp of the Pellet (Prone or Sitting)**

Left | Right | **L | R**

12 months

Fine Pincer Grasp (test by grasping a pin)
Between fingertips or fingernails, distal thumb joint flexed (2) g

10 months



Pincer Grasp
Between distal pads of thumb and index finger, distal thumb joint slightly flexed (2) g
Thumb opposed (2) p t

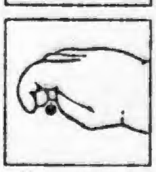
9 months

Inferior-Pincer Grasp
Between ventral surfaces of thumb and index finger, distal thumb joint extended (3) g
Beginning thumb opposition (3) p t

8 months

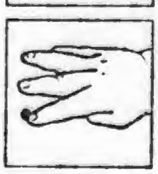
Scissors Grasp
Between thumb and side of curled index finger, distal thumb joint slightly flexed (3) g
Proximal thumb joint extended (3) p t

7 months



Inferior-Scissors Grasp
Raking object into palm with adducted, totally flexed thumb and all flexed fingers OR:
Raking object into palm with adducted, totally flexed thumb and 2 partly extended fingers (3) g

6 months

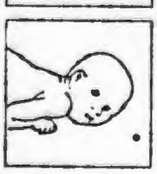


Raking and contacting object (3) g
Thumb adducted (3) p t
Proximal thumb joint flexed (3) p t
Distal thumb joint flexed (3) p t

5 months

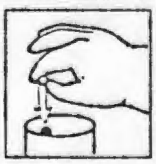
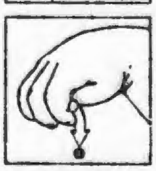
No attempt to grasp (3) g
Visually attends to object (3) v

Natal



No grasp (3) g
No visual attention to object (3) v

g	v	m x	m s e w	m̄	m̄ v	gn	p t

Developmental Levels (Left / Right)		Pattern Components (L / R)	Release of the Pellet (Sitting)
15 months			Precise release into small container (2) 1 4 Wrist extended (2) p w
14 months			Clumsy release into small container (3) 1 4
12 months			Unsuccessful release into small container (3) 1 4
10 months			Controlled release into large container (2) 1 3
9 months			Clumsy release into large container (3) 1 3 Wrist straight (3) p w Transfer (2) x
8 months			Unsuccessful release into large container (3) 1 3 Clumsy release above surface (3) 1 2 Unsuccessful attempt to transfer (3) x Attempt to locate visually by supinating, results in involuntary release (3) 1
7 months			Involuntary release above surface without awareness (3) 1 2 Wrist flexed (3) p w
Natal			No release (no grasp) (3) 1

Request		Observe	
(1)	Remove pellet from pill box	(1)	/ v / m / g
(2)	Pour out of container	(2)	m̄, v, m x
(3)	Grasp pellet from table.	(3)	g / p w h t
(4)	Transfer to other hand and back.	(4)	g / 1
(5)	Release against / above surface	(5)	1 / p w h t
(6)	Release into large and small container.	(6)	1 / p w h t

x	1	1 2	1 3	1 4	p w

Explanatory notes -

Appendix A

p 130

- Initial information - obtained from the child's file and other therapists.
- Teachers' Judgement (of intelligence) - obtained from form in Appendix B.
- See p 77-79 for the explanation of the rest of this page and p 131.

p 132

- The child's best performance is encouraged in the following sections even though two or three trials may be necessary.
- The first key needs to be referred to for all of the following instructions.

Action or aspect to observe - includes symbols for all the actions or aspects of development that are specifically observed before judgements are made.

Body parts involved - include symbols for all the body parts observed - m e h will therefore alert the therapist to look at the movement (and placement) of the elbow and the hand.

To explain the use of the key - consider the following example : looking at p 133:-

If the child's hands are partly open: Looking at the lowest level of position of the hand (p h) first, "hands flexed" (3 months) is no longer present this would therefore score 3 i.e. "all pattern components replaced".

The next possibility is "Hands partly open" at 4 months.
Since this pattern is present, the score would be 2 i.e. "all pattern components present" - This gives a total of 3 + 2 = 5 for p h.
If the child can grasp at the adult level of appropriate finger extension he will get 3 each for "Hands flexed; Hands partly open; Hands open; Excessive finger extension; Excessive M C P extension (since all of these patterns had been replaced). He will score 2 for "Appropriate finger extension" - which has all the pattern components present. The total of p h for this child would therefore be (3 x 5) = 15 + 2 = 17.

The highest possible score of each item i.e. 2 or 3 is indicated next to the item.

p 133

The instruction to the therapist is followed by body parts to observe and also aspects and/or actions to observe. See p 132 for explanation of abbreviations.

p 134 & p 135

The therapist makes the requests (See p 134) of the child in the sequence stated and during each response the action of the indicated body parts are observed to decide on the appropriate score.

p 136 & p 137

The instructions on p 137 are applicable to both of these pages.

APPENDIX B

HANDFUNCTION STUDY ASSESSMENT - TEACHER'S JUDGEMENT

NAME CLASS TEACHER

Intelligence	Very dull	Dull	Average	Bright	Very Bright	
	Very Poor	Poor	Fair	Good	Excellent	
Ability to do handwork						
Ability to draw						
Ability to concentrate						
Motivation to try and do						

Fig 3 Interreliability of Testers - Erhardt items

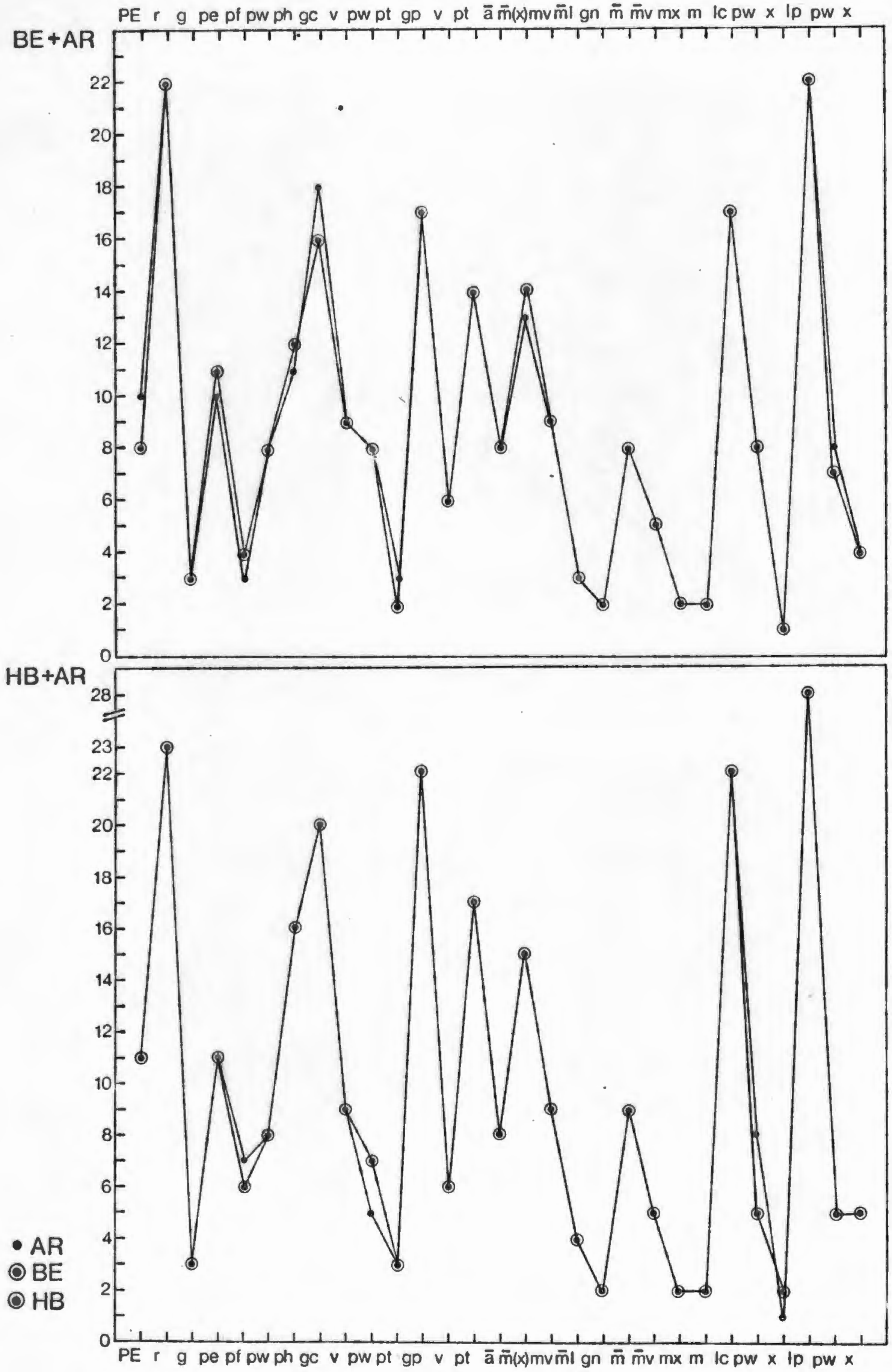
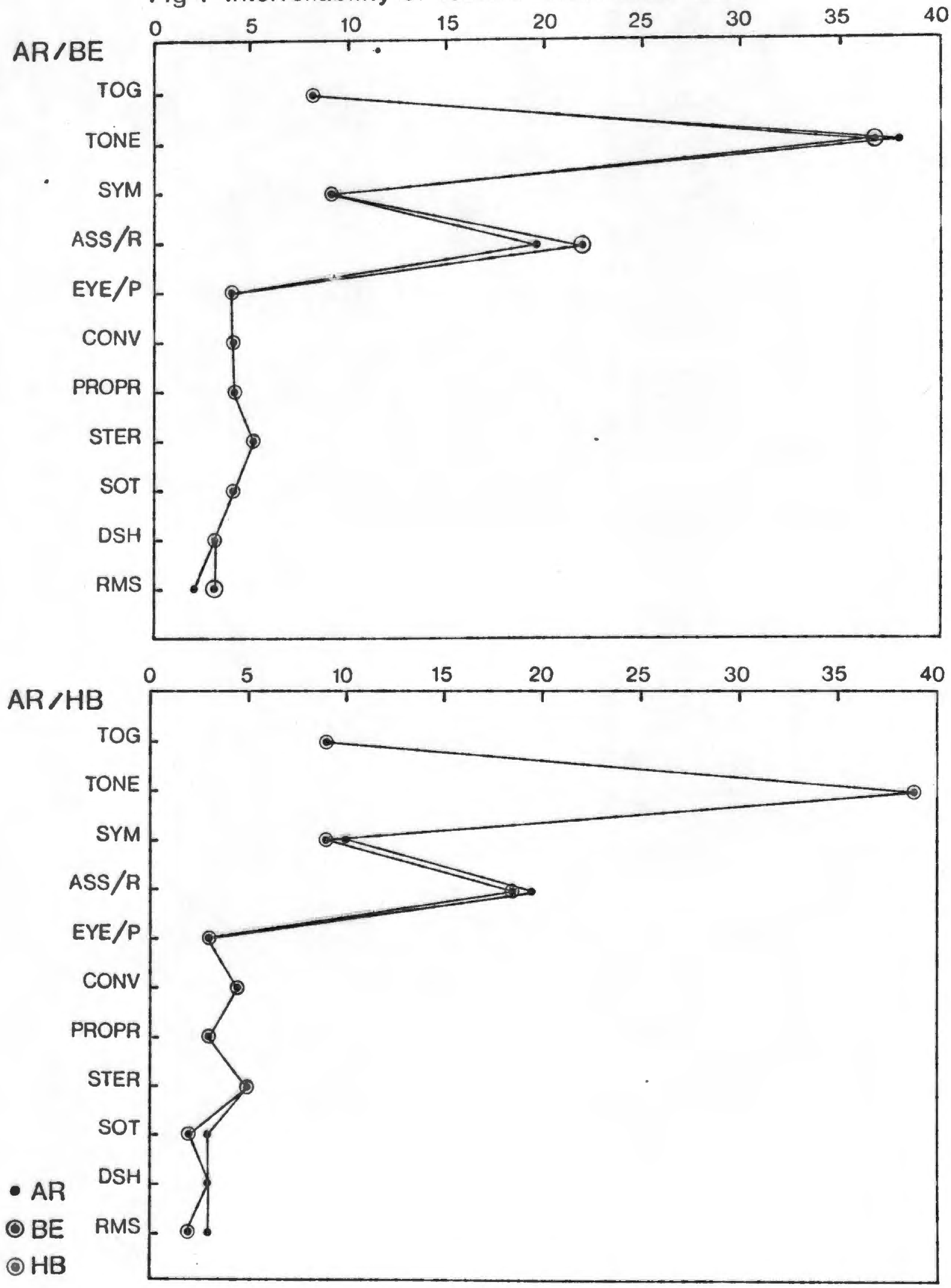


Fig 4 Interreliability of Testers - Additional Items



APPENDIX C INTERRELIABILITY OF TESTERS (BE and AR) and (HB and AR)

Independent scores were given by each therapist. After discussion the therapists agreed to a compromise where there were discrepancies. The figures in brackets below are the discrepancies from the finally agreed figure.

Examples of discrepancies between testers.

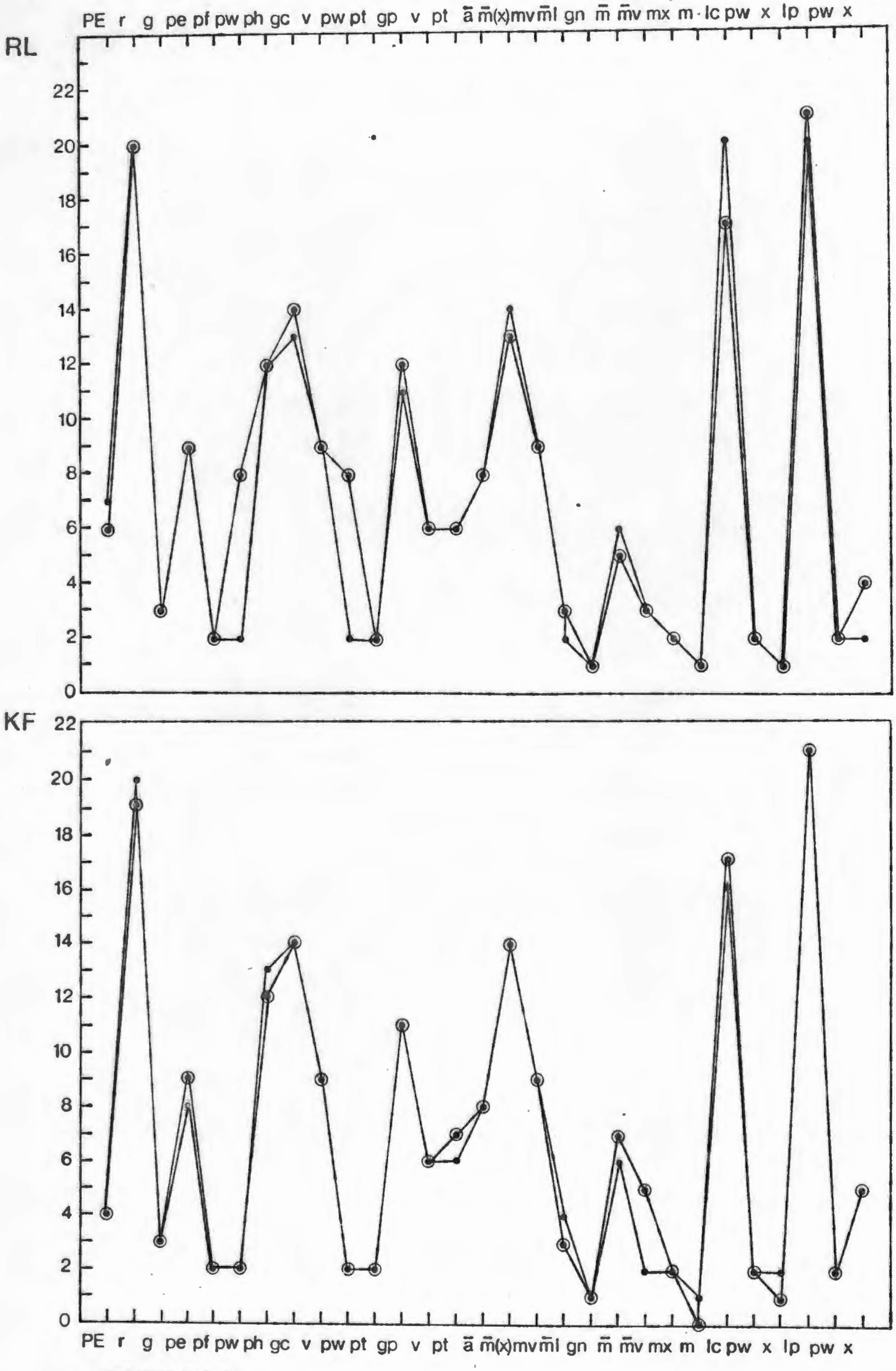
Protective extension (AR + 2)	- BE judged the child's hand position more strictly.
Grasp (AR + 1, BE - 1)	- AR judged the grasp as radial digital and BE as radial palmar.
Manipulation (bilateral) (AR - 1)	- AR saw the affected hand of the child as rather rigid and passive at first while BE thought bilateral interaction to be good.
Transfer of the cube (HB + 1)	- HB initially considered the transfer to be adept.
Position of the forearm (AR - 2)	- HB did not agree that any supination was present.
Position of the wrist	
with grasp (AR - 2)	- AR considered the wrist to be straight while HB saw it as slightly extended.
with release of cube (HB - 3)	- HB considered the wrist to be straight but then agreed that it was actually extended.
with release of pellet (AR + 1)	- AR judged the wrist to be extended but agreed that it could be partly extended.
Additional items	
Tone (BE - 1)	- BE at first considered mild tone to be present in the child's shoulder.

Associated Reactions

(AR - 0, 5, BE + 2) - These were initially judged to be less with lifting of the head, abduction of the unaffected leg and placing of the pellet by BE.

(AR + 1) - HB judged associated movements to be severe while AR judged them to be moderate with squeezing of the fingers.

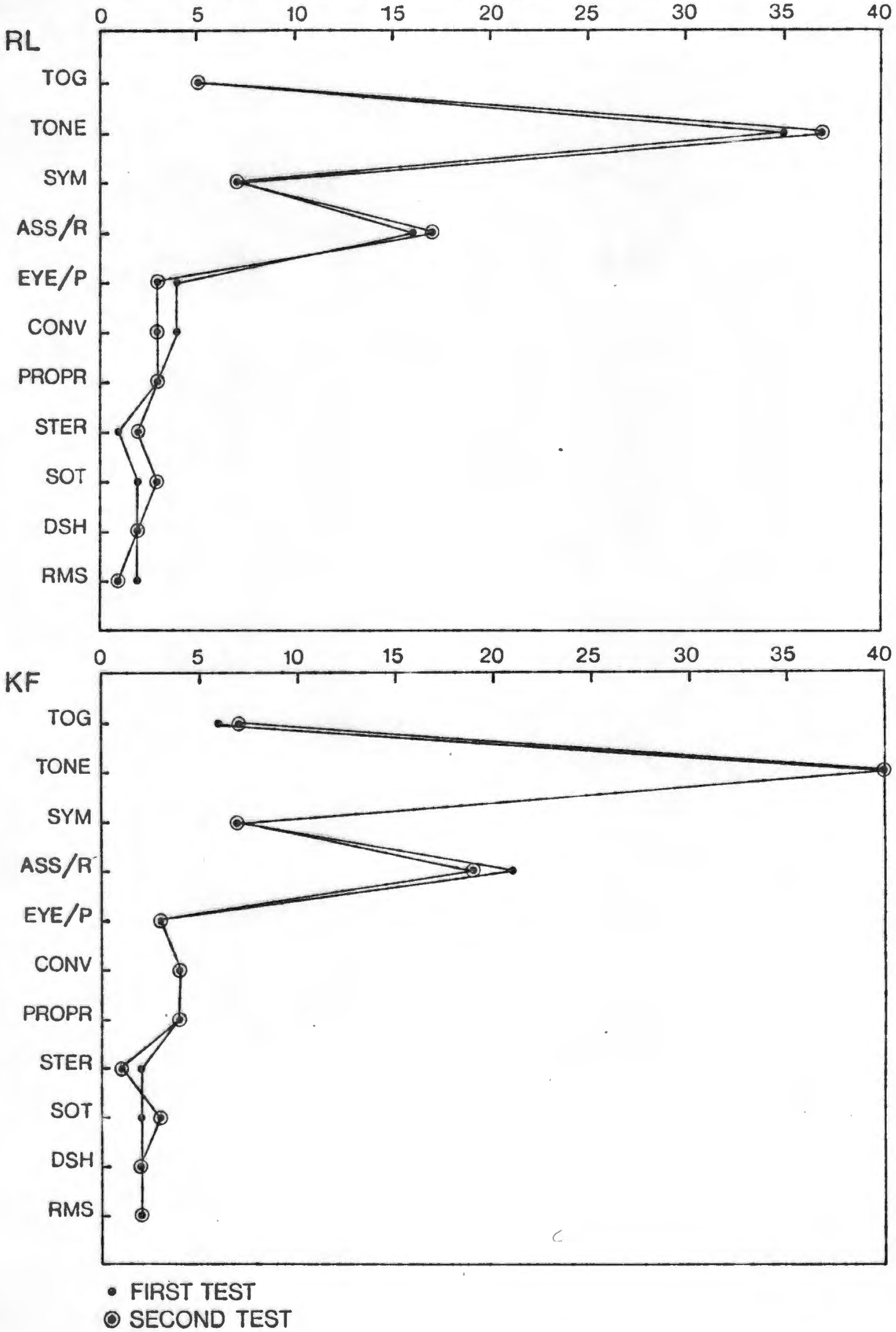
Fig 5 Test - Retest Reliability - Erhardt items



• FIRST TEST

◉ SECOND TEST

Fig 6 Test - Retest Reliability - Additional Items



APPENDIX D TEST RETEST RELIABILITY (RL and KF).

Examples of Discrepancies between first and second assessment

Erhardt items

Protective extension (-1)	- this could not be elicited backwards for RL at the second assessment.
Approach (-1)	- approach circular at first, angular at second assessment of KF.
Grasp cube (+1)	- at first assessment of RL his middle finger appeared to be followed by the ring and little finger - not seen at second assessment.
Grasp pellet (+1)	- RL managed to use a scissors grasp at second assessment.
Manipulate throw cube (+1)	- RL managed to throw the cube at the second assessment.
(-1)	- KF used momentum instead of release to throw the cube at the second assessment.
Release cube (-3)	- RL very carefully released the cube at the first assessment and did not take so much care the second time.
(+1)	- KF released against the surface of the container at first and managed without this support when specially careful at the second assessment.
Position wrist - with approach (+6) with grasp (+6)	- wrist flexed at first, extended at second assessment of approach and grasp of RL.
Position hand (-1)	- ip joints were also hyperextended at the second assessment of KF

Additional items

Associated Reactions (-2)	- KF had slightly more associated reactions with abduction of his unaffected leg and placing of the pellet.
Tone (+2)	- RL had slightly less tone in the trunk, affected fingers and thumb and slightly more in his affected wrist.
Eye pursuit (-1)	- RL had less steady eye pursuit after watching a video before the second assessment.
Stereognosis (+1)	- RL could identify only the marble at first but could also identify the cotton reel subsequently.
(-1)	KF could identify the button and cube initially and then only the cube.

APPENDIX E

TREATMENT PROGRAMME OF L.S.

See P. 153 for explanation of approach during treatment.

SESSION 1

A.* Seated on a treatment ball, equilibrium reactions were elicited. Tone of the trunk was normalised by encouragement of rotation to alternate sides while walking on hands.

B.* While astride a roll, she pushed a twenty centimetre (cm) ball along with the affected hand towards skittles on the unaffected side.
Still astride the roll she was encouraged to take weight on both hands while the therapist slowly pushed the roll along to either side. She therefore needed to take her weight on her hands while lifting her seat to allow the movement of the roll.

C.* Sitting on an orange ball (supported by the therapist) she played noughts and crosses with the affected hand. The playing area was against the wall at shoulder level on her unaffected side. The pieces were cylindrical pill boxes (diameter 3 cm). Following this she removed large sterofoam shapes (2 cm x 5 cm x 8 cm) (from the same position) with her affected hand and placed them in a container on her affected side (apples from an apple tree).

SESSION 2

A. As above.

B. With open hands she pushed the ball around the room reciprocally with the upper lims.
While astride a roll she reached out to remove cardboard cylinders (4 cm diameter) at shoulder level on the unaffected side with the affected hand and dropped them into a container on her other side.

C. While astride a roll blow football was played at floor level towards the unaffected and then the affected side. An empty detergent bottle grasped in a radial palmar grasp by both hands was used to blow a small wisp of cotton wool along to the goal posts. From the same position thumb printing on a strip of paper was

* Refer p 86 for explanations of A, B and C.

done on the unaffected side at shoulder level using the affected hand. (The strip was stapled together to become a hat).

SESSION 3

A. As above.
B. While prone over a roll and with the therapist controlling her legs, she walked forward on open hands. She then took weight on one hand to pick up a bean bag to put into a flat container with the other hand, alternating hands.
C. While astride a roll she squeezed glue into a flat container in front of her using both hands around the cylindrical glue bottle. She grasped a wooden block (2½ cm x 2½ cm x 5 cm) with sponge on one side with the affected hand to smooth glue onto the shape of a fish. She tore paper using both hands in front and placed these on the glued surface of the fish on the floor at her unaffected side using alternate hands.

SESSION 4

A. As above.
B. She walked on her hands on shapes of different textures of carpet (crossing a river).
   Astride a roll she pushed a yellow treatment ball along with both hands simultaneously to skittles at her unaffected side.
C. She used a flat piece of sponge to smooth glue onto a picture with the affected hand and smoothed this picture around a plastic bottle, using both hands.
   She smoothed down the folds of a fan as the therapist folded it. She used individual fingers to apply paint in various patterns over the fan.

SESSION 5

A. As above.
B. While seated on the red treatment ball, she rolled the orange ball around first to one, then the other side using open hands reciprocally.
   She used a towel grasped at the corners in both hands, between her

and the therapist, (while astride a block) to throw up bean bags as high as possible.

From the same position she caught a small flat stuffed orange bag between the two hands and threw it towards the therapist in front.

C. While astride a block she placed large folded cards to one then to the other side on the floor. She used bean bags in one then the other hand to knock these cards over (taking weight on the resting hand).

She picked shells one at a time with one hand and placed them in glue and onto the surface of a box (alternating hands while weightbearing with the other hand). She gathered the rest of the shells with the affected hand and dropped them into a bag.

She smoothed folds of a hat folded by the therapist.

SESSION 6

A. As above.

B. Sitting on an orange treatment ball she walked a yellow treatment ball to the one then the other side.

She stood facing a wall with one then the other foot placed on a block (taking weight against the wall with the affected hand). She then took pictures from a table at the unaffected side and pressed them against the wall arranging them to make a story. (They already had Prestic attached to them).

She did kneelstanding on the floor. Then she accepted and threw a flat liquifruit bag from between her two open hands to try and hit a chair.

C. While astride a roll, she printed linoprint pictures attached to a 4 cm diameter pillbox on a strip against the wall at shoulder level. She used the affected hand to print on the unaffected side. She folded this cardboard strip working on a table in front of her in order to display the pictures.

SESSION 7

A. As above, then she had to get to four-foot kneeling and to side-sitting to one, then the other side. The therapist moved her forwards over the ball to elicit forward protective extension on the floor.

B. She walked the ball forwards by walking backwards on her open hands while her legs were held by the therapist.
   She walked on her hands over the ball towards the next activity.
   She then had to throw the yellow treatment ball up and over her head (in standing).

C. While kneeling at a small stool she divided clay into two pieces and rolled them into two balls using both hands together and rolling them on the surface with alternate hands.
   She used individual fingers of the affected hand to paint the sides of square macaroni pieces held in her other hand.
   She threaded these pieces onto a wire using both hands alternatively changing the roles of manipulating the wire on the macaroni piece.

SESSION 8

A. As at session one; then over the orange ball walking with open hands onto the floor.

B. Grasping a cardboard roll horizontally between her hands, she hit a small cardboard cylinder (held by the therapist) while in kneel standing.

C. She sat on a block in front of the wall, then rotated backwards over the block bearing weight with one hand, while picking up counters for noughts and crosses with the other hand and placing them. She alternated hands.
   She caught and threw a small red cushion between her open hands while kneel-standing.

D. Astride a roll she rolled clay into a large ball between her hands and on the table in front of her.
   She flattened this with both hands. (The therapist pierced a hole for later threading as a hanger).
   She chose a picture by sorting through cards on a table using both flat hands.
   She smoothed folds as the therapist folded a boat on the table.
   She opened a large "Pritt" by using both hands. She smoothed the "Pritt" (using the affected hand) on the picture against the wall at shoulder level on her unaffected side.
   She pressed the picture onto the boat using both hands on the table.

She played with a finger puppet placing the index and middle finger through the holes as legs. She tried to make the puppet walk by moving the fingers alternately.

SESSION 9

A. As session 8; then she walked the ball back into the corner with her hands while her legs were held by the therapist.

B. In four-foot kneeling while taking weight on one hand she kept a balloon in the air with the other hand. Alternate hands were used.
Over the roll she walked forwards on her hands. She grasped mat pieces held by the therapist on either side while taking weight on the other hand. The pieces were placed to "build a road". Then she walked on the "road" while her legs were still controlled by the therapist.
Kneelstanding, she took a balloon held by the therapist between her open hands and threw it in the air.

C. She repeated the printing activity described in Session 6 C but printed on cards that were later folded in two rather than on a strip.

SESSION 10

A. As in session 1. Then sitting on the ball and moving while supported by her pelvis, she was encouraged to abduct her arms to keep her equilibrium. She then rotated to a roll behind her and was encouraged to make the roll move walking it with open hands.

B. She pulled along a sandbag on a rope alternating while astride a roll.
She walked along on her hands on the carpet pieces. Taking weight on one hand, she removed a beanbag from a "road" with the other hand as her legs were held by the therapist. Alternate hands were used.
Sitting astride a roll she took weight on one hand while taking a sandbag from that side on the floor with the other hand and placing these in a container in front. She alternated sides.
Standing steadily, feet placed firmly, she took a liquifruit bag between two hands from the therapist and threw this up in the

air each time.

C. She grasped a durablock in each hand and drew lines simultaneously on a sheet against the wall while standing.
   She chose shells (alternating hands) to place into glue and onto a hardboard back-ground to make a picture, while astride a roll. From the same position she rolled three round beads using both hands.

SESSION 11

A. As session 1. Then she walked her hands around the ball to the back and returned to walk up the ball repeating this on the other side.

B. A towel was held between her two hands. She pushed along a small yellow treatment ball in different directions while sitting astride the end of a roll.
   With her legs held in abduction over a roll, she stabilised one arm in weightbearing while building with sponge blocks with the other hand. She alternated her hands.

C. Astride the roll, she picked up sponge blocks on one side and put them into a container on the other side of the roll. She ran sand through her supinated hands then smoothed the sand, and patted it. She drew lines in the sand using both hands then rubbed her hands clean from the sand. She painted the clay beads made previously, on the table in front of her while astride a block. This was done by putting paint on the thumb and fingers of her affected hand and rubbing the bead between the fingers.

SESSION 12

A. As session 11.

B. Standing with one foot up on a block facing a wall she took down 5 cm cardboard rolls from the wall with her affected hand to put them into a container.
   She walked on her hands in the longsitting position with both hands behind her seat. Lifting up her seat she walked forwards then backwards in a crab walk.
   In a standing position with one foot up she took flat sterofoam

pieces (2 cm x 5 cm x 8 cm) between both open hands and dropped them on the floor to see how they fell.

C. Weightbearing on one hand in sidesitting on the floor, she printed on cloth.
This was done to one side then to the other, using a large flat lino block that she could grasp and yet use with an open hand.

General Approach in Treatment

The activities used and the appropriate treatment principles were kept as similar as possible for all the children in the experimental group to achieve as much control as possible. Emphasis varied slightly depending on the needs of each child and presentation of the activities as play differed according to the age and interest of each child.

The activities of session 1 could, for example, be used as follows for L.S. who was 5 years 5 months.

A - Using symbolic play the ball could be a moving ship at sea on which she needed to stay. walking around on her hands could be a means to see whether the fish peeping from the water wanted a worm and then to the other side to see what the seal wanted, and so on. She could be encouraged to move quietly and carefully not to frighten the animals away.

B - In pushing the ball towards the skittles she tried to disturb as many as possible competing with herself.
- She could then be on a horse which was trying to throw her off. By pushing on her hands and lifting her seat she needed to try and keep on the horse as the therapist moved the roll to the one side of the room, then the other side.

C - The play activity, noughts and crosses, challenged her to beat the therapist in a game which she enjoyed. After this she tried to pick all the apples from the apple tree. Section C of most other sessions included some types of constructive play to elicit the required hand movements.

TABLE 8

TONE, SYMMETRY AND ASSOCIATED REACTIONS

Exp. Group	Tone			Symmetry			Ass Re-actions			Ass mvt. $\bar{c}$ Man. (mx)			Control Group	Tone			Symmetry			Ass Re-actions			Ass mvt. $\bar{c}$ Man. (mx)		
	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss		B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss
GL	32	35	+3	4	7	+3	24	22	-2	2	2	=	CJ	29	37	+8	8	10	+2	21	22	+1	2	2	=
AD	34	40	+6	8	5	-3	15	18	+3	2	2	=	CP	31	34	+3	5	4	-1	13	14	+1	2	2	=
JW	41	40	-1	11	9	-2	19	19	=	2	2	=	ST	41	39	-2	12	10	-2	18	22	+4	2	2	=
CR	42	42	=	11	11	=	19	23	+4	2	3	+1	SM	40	41	+1	5	7	+2	19	18	-1	2	3	+1
LS	44	38	-6	6	9	+3	20	19	-1	2	2	=	DK	40	38	-2	9	8	-1	19	21	+2•	2	2	=
RF	39	38	-1	7	3	-4	18	21	+3	2	2	=	FS	42	41	-1	10	10	=	23	23	=	3	3	=
IM	41	40	-1	8	4	-4	23	24	+1	2	2	=	EJ	39	38	-1	9	4	-5	17	21	+4	2	2	=
DD	39	38	-1	5	8	+3	17	18	+1	2	2	=	BJ	42	42	=	8	5	-3	20	21	+1	2	2	=
RE	39	41	+2	7	11	+4	18	21	+3	3	3	=	EL	38	38	=	9	6	-3	20	20	=	2	2	=
NJ	39	40	+1	9	11	+2	18	21	+3	2	2	=	JG	43	42	-1	10	12	+2	23	23	=	3	2	-1
Gains			+12			+15			+18			+1				+12			+6			+13			+1
Losses			-10			-13			-3			=				-7			-15			-1			-1
Total	390	392	+2	76	78	+2	191	206	+15	21	22	+1		385	390	+5	85	76	-9	193	205	+12	22	22	=
Ave. loss or gain +			+0,2			+0,2			+1,5			+0,1				+0,5			-0,9			+1,2			
%			0,5%			2,6%			7,9%			4,8%				1,3%			10,6%			6,2%			

TABLE 9

PROTECTIVE EXTENSION AND REACH

Exp. group	Prot. ext.			Reach			Control group	Prot. ext.			Reach		
	B	A	Gain Loss	B	A	Gain Loss		B	A	Gain Loss	B	A	Gain Loss
GL	2	3	+1	22	20	-2	CJ	7	6	-1	22	17	-5
AD	7	7	=	20	20	=	CP	5	5	=	20	20	=
JW	10	9	-1	22	23	+1	ST	8	8	=	22	17	-5
CR	11	11	=	23	23	=	SM	9	10	+1	23	23	=
LS	9	9	=	22	23	+1	DK	9	10	+1	23	23	=
RF	7	7	=	20	20	=	FS	7	9	+2	23	23	=
IM	5	6	+1	18	20	+2	EJ	7	5	-2	20	20	=
DD	5	6	+1	23	20	-3	BJ	7	10	+3	20	20	=
RE	8	10	+2	23	23	=	EL	8	6	-2	22	21	-1
NJ	11	10	-1	23	23	=	JG	10	11	+1	21	23	+2
Gains			+5			+4	Gains			+8			+2
Losses			-2			-5	Losses			-5			-11
Total	75	78	+3	216	215	-1	Total	77	80	+3	216	207	-9
Ave + % gain or loss			0,3 4%			-0,1 0,5%	Ave + % gain or loss			0,3 3,9%			-0,9 4,2%

TABLE 10 SCAPULAR MOBILITY AND STABILITY AND DISSOCIATION OF SHOULDER, ELBOW AND WRIST

Exp. Group	Scapula on trunk B	Scapula on trunk A	Scapula on trunk Gain Loss	Diss Scap. Hum. B	Diss Scap. Hum. A	Diss Scap. Hum. Gain Loss	Rec. Scap. B	Rec. Scap. A	Rec. Scap. Gain Loss	Diss s/e/w B	Diss s/e/w A	Diss s/e/w Gain Loss
GL	3	3	=	1	2	+1	2	0	-2	0	0	=
AD	3	3	=	2	1	-1	2	1	-1	1	2	+1
JW	4	4	=	4	4	=	3	3	=	2	1	-1
CR	2	3	+1	3	2	-1	3	3	=	2	2	=
LS	3	3	=	2	3	+1	3	2	-1	2	2	=
RF	3	2	-1	2	2	=	2	2	=	1	1	=
IM	3	2	-1	3	2	-1	3	2	-1	1	1	=
DD	4	3	-1	2	3	+1	3	3	=	2	1	-1
RE	3	3	=	4	3	-1	3	3	=	2	2	=
NJ	2	3	+1	3	3	=	2	3	+1	2	2	=
Gains			+2			+3			+1			+1
Losses			-3			-4			-5			-2
Total	30	29	-1	26	25	-1	26	22	-4	15	14	-1
Ave & % Gains/ Losses			-0,1 3,3%			-0,1 3,8%			-0,4 15,4%			-0,1 6,7%

Control Group	Scapula on trunk B	Scapula on trunk A	Scapula on trunk Gain Loss	Diss Scap. Hum. B	Diss Scap. Hum. A	Diss Scap. Hum. Gain Loss	Rec. Scap. B	Rec. Scap. A	Rec. Scap. Gain Loss	Diss s/e/w B	Diss s/e/w A	Diss s/e/w Gain Loss
CJ	2	2	=	1	2	+1	1	1	=	1	1	=
CP	3	2	-1	1	2	+1	2	2	=	1	1	=
ST	3	3	=	3	1	-2	2	2	=	2	2	=
SM	3	3	=	3	3	=	3	3	=	2	2	=
DK	4	3	-1	4	4	=	3	2	-1	2	1	-1
FS	4	2	-2	3	2	-1	3	2	-1	2	1	-1
EJ	2	3	+1	2	3	+1	2	3	+1	2	1	-1
BJ	2	3	+1	2	3	+1	2	3	+1	1	1	=
EL	4	2	-2	3	2	-1	3	2	-1	2	1	-1
JG	4	4	=	3	4	+1	3	3	=	2	2	=
Gains			+2			+5			+2			=
Losses			-6			-4			-3			-4
Total	31	27	-4	25	26	+1	24	23	-1	17	13	-4
Ave & % Gains/ Losses			-0,4 12,9%			0,1 4%			-0,1 4,2%			-0,4 23,5%

TABLE 11

POSITION OF ELBOW, FOREARM, HAND AND THUMB

Exp. Group	Appr. pe B	Appr. pe A	Gain Loss	Appr. pf B	Appr. pf A	Gain Loss	Appr. ph B	Appr. ph A	Gain Loss	Grasp Cube pt B	Grasp Cube pt A	Gain Loss	Grasp Pellet pt B	Grasp Pellet pt A	Gain Loss	Control Group	Appr. pe B	Appr. pe A	Gain Loss	Appr. pf B	Appr. pf A	Gain Loss	Appr. ph B	Appr. ph A	Gain Loss	Grasp Cube pt B	Grasp Cube pt A	Gain Loss	Grasp Pellet pt B	Grasp Pellet pt A	Gain Loss
GL	3	5	+2	2	2	=	10	13	+3	2	2	=	6	6	=	CJ	10	11	+1	3	2	-1	8	10	+2	2	2	=	6	6	=
AD	8	8	=	5	4	-1	13	12	-1	2	2	=	6	6	=	CP	8	8	=	2	2	=	13	12	-1	2	2	=	6	6	=
JW	11	11	=	5	6	+1	13	12	-1	2	2	=	6	10	+4	ST	10	10	=	5	2	-3	15	13	-2	2	2	=	17	15	-2
CR	11	11	=	7	6	-1	15	16	+1	3	3	=	16	16	=	SM	11	11	=	5	5	=	13	14	+1	3	3	=	17	16	-1
LS	9	10	+1	2	3	+1	13	13	=	2	2	=	10	10	=	DK	11	11	=	2	4	+2	15	13	-2	2	2	=	6	7	+1
RF	9	8	-1	2	2	=	13	13	=	2	2	=	12	14	+2	FS	11	11	=	2	2	=	13	14	+1	2	2	=	6	7	+1
IM	10	11	+1	5	4	-1	13	13	=	2	2	=	14	9	-5	EJ	8	11	+3	5	2	-3	12	12	=	2	2	=	9	11	+2
DD	11	10	-1	2	2	=	13	12	-1	2	2	=	6	6	=	BJ	9	10	+1	3	2	-1	12	13	+1	2	2	=	10	6	-4
RE	11	11	=	2	3	+1	16	16	=	3	3	=	17	17	=	EL	10	11	+1	4	4	=	12	12	=	2	2	=	14	14	=
NJ	11	11	=	6	6	=	16	14	-2	3	3	=	17	17	=	JG	10	11	+1	7	7	=	14	14	=	3	3	=	17	15	-2
Gains			+4			+3			+4			=			+6				+7			+2			+5			=			+4
Losses			-2			-3			-5			=			-5				-			-8			-5			=			-9
Total	94	96	+2	38	38	=	135	134	-1	23	23	=	110	111	+1		98	105	+7	38	32	-6	127	127	=	22	22	=	108	105	-5
Ave + % Gains or Losses			0,2 2,1%						-0,1 0,7%						0,1 0,9%				0,7 7,1%			-0,6 15,8%			-			-			-0,5 2,8%

TABLE 12

POSITION OF THE WRIST

Exp. Group	Approach B	Approach A	Approach Gain Loss	Grasp cube B	Grasp cube A	Grasp cube Gain Loss	Release cube B	Release cube A	Release cube Gain Loss	Release pellet B	Release pellet A	Release pellet Gain Loss	Total wrist B	Total wrist A	Total wrist Gain Loss
GL	2	2	=	2	2	=	2	2	=	2	2	=			
AD	5	8	+3	5	2	-3	2	2	=	5	2	-3			
JW	7	5	-2	2	5	+3	2	5	+3	8	5	-3			
CR	8	8	=	6	5	-1	8	5	-3	8	8	=			
LS	4	5	+1	3	4	+1	8	4	-4	7	5	-2			
RF	2	5	+3	5	2	-3	2	2	=	3	2	-1			
IM	8	8	=	8	8	=	8	8	=	8	8	=			
DD	5	2	-3	8	5	-3	2	2	=	2	4	+2			
RE	8	8	=	5	5	=	5	2	-3	5	4	-1			
NJ	8	8	=	7	8	+1	8	8	=	5	8	+3			
Gains			+7			+5			+3			+5			
Losses			-5			-10			-10			-10			
Total	57	59	+2	51	46	-5	47	40	-7	53	48	-5	208	193	-15
Ave. & % gain or loss			+0,2 3,5%			-0,5 9,8%			-0,7 14,9%			-0,5 9,4%			-1,5 7,2%

Control Group	Approach B	Approach A	Approach Gain Loss	Grasp cube B	Grasp cube A	Grasp cube Gain Loss	Release cube B	Release cube A	Release cube Gain Loss	Release pellet B	Release pellet A	Release pellet Gain Loss	Total wrist B	Total wrist A	Total wrist Gain Loss
CJ	5	2	-3	2	2	=	2	2	=	2	2	=			
CP	8	5	-3	8	5	-3	7	8	+1	8	8	=			
ST	5	5	=	5	2	-3	5	2	-3	5	2	-3			
SM	8	8	=	8	7	-1	8	2	-6	8	8	=			
DK	8	8	=	5	8	+3	8	6	-2	7	4	-3			
FS	8	8	=	7	7	=	8	8	=	2	7	+5			
EJ	5	2	-3	5	3	-2	5	2	-3	2	4	+2			
BJ	5	8	+3	5	2	-3	2	8	+6	2	5	+3			
EL	8	8	=	8	8	=	8	8	=	7	8	+1			
JG	5	8	+3	8	8	=	8	8	=	8	8	=			
Gains			+6			+3			+7			+11			
Losses			-9			-12			-14			-6			
Total	65	62	-3	61	52	-9	61	54	-7	51	56	+5	238	224	-14
Ave. & % gain or loss			-0,3 4,6%			-0,9 14,8%			-0,7 11,5%			+0,5 8,9%			-1,4 -5,9%

TABLE 13 VISUAL DEPENDANCE, PURSUIT AND CONVERGENCE

	mv cube			mv pellet			Visual pursuit			Visual convergence				mv cube			mv pellet			Visual pursuit			Visual convergence		
Exp. Group	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	Control Group	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss
GL	8	8	=	2	2	=	4	3	-1	4	3	-1	CJ	9	8	-1	4	2	-2	4	2	-2	3	2	-1
AD	9	9	=	5	2	-3	4	3	-1	4	3	-1	CP	9	9	=	4	2	-2	3	4	+1	3	3	=
JW	9	9	=	5	4	-1	3	4	+1	4	4	=	ST	9	9	=	4	2	-2	3	3	=	4	3	-1
CR	9	9	=	5	5	=	4	3	-1	2	1	-1	SM	9	9	=	5	5	=	3	1	-2	3	1	-2
LS	9	8	-1	5	2	-3	4	4	=	4	4	=	DK	9	9	=	5	2	-3	4	4	=	4	4	=
RF	9	9	=	5	5	=	4	4	=	4	4	=	FS	9	8	-1	4	2	-2	3	4	+1	4	4	=
IM	9	8	-1	4	2	-2	4	3	-1	4	3	-1	EJ	9	9	=	5	5	=	4	4	=	4	4	=
DD	9	9	=	3	2	-1	3	3	=	4	4	=	BJ	9	9	=	5	2	-3	4	3	-1	3	4	+1
RE	9	9	=	5	5	=	3	3	=	0	2	+2	EL	9	8	-1	5	2	-3	4	4	=	4	3	-1
NJ	9	9	=	5	5	=	3	3	=	4	3	-1	JG	9	9	=	5	5	=	4	4	=	4	4	=
Gains									+1			+2										+2			+1
Losses			-2			-10			-4			-5				-3			-17			-5			-5
Total	89	87	-2	44	34	-10	36	33	-3	34	31	-3		90	87	-3	46	29	-17	36	33	-3	36	32	-4
Ave & % Gains Losses			-0,2 2.2%			-1,0 22,7%			-0,3 8,3%			-0,3 8,8%				-0,3 3,3%			-1,7 37%			-0,3 8,3%			-0,4 11,1%

TABLE 14

PROPRIOCEPTION STEREOGNOSIS AND TAKING OFF GARMENT

	Proprio-ception	Diff B + A	Stereog-nosis	Diff B + A	Take off garment	Diff B + A		Proprio-ception	Diff B + A	Stereog-nosis	Diff B + A	Take off garment	Diff B + A
GL	3–3	=	1–2	+1	2–2	=	CJ	0–0	=	1–2	+1	7–4	–3
AD	3–4	+1	1–3	+2	7–7	=	CP	4–4	=	1–1	=	7–7	=
JW	4–3	–1	1–4	+3	8–8	=	ST	4–3	–1	4–5	+1	7–8	+1
CR	4–4	=	5–5	=	7–9	+2	SM	4–4	=	5–5	=	7–8	+1
LS	1–2	+1	2–0	–2	7–8	+1	DK	4–4	=	2–2	=	9–8	–1
RF	3–4	+1	5–5	=	6–7	+1	FS	3–3	=	2–4	+2	7–8	+1
IM	2–2	=	0–2	+2	8–8	=	EJ	4–4	=	5–5	=	7–7	=
DD	0–4	+4	2–2	=	6–6	=	BJ	4–4	=	0–1	+1	8–7	–1
RE	4–4	=	5–5	=	6–8	+2	EL	4–3	–1	5–5	=	8–8	=
NJ	3–4	+1	5–5	=	9–9	=	JG	4–4	=	3–3	=	9–9	=
+		+8		+8		+6			+0		+5		+3
–		–1		–2		–0			–2		–0		–5
Total	27–34	+7	27–33	+6	66–72	+6		35–33	–2	28–33	+5	76–74	–2
Ave Gain or loss		+0,7		+0,6		+0,6			–0,2		+0,5		–0,2
% Gain or loss		25,9%		22,2%		9,1%			5,7%		17,9%		

TABLE 15 MOTIVATION AND DISTRACTABILITY/CONCENTRATION JUDGED BY OT AND TEACHER

	Motivation OT			Motivation Teacher			Distract. OT			Concentr. Teacher				Motivation OT			Motivation Teacher			Distract. OT			Concentr. Teacher		
Exp. Group	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	Control Group	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss
GL	1	3	+2	2	2	=	2	3	+1	1	2	+1	CJ	2	2	=	1	1	=	1	1	=	1	0	-1
AD	1	2	+1	1	1	=	1	1	=	2	1	-1	CP	2	2	=	3	3	=	1	2	+1	2	3	+1
JW	3	4	+1	2	4	+2	3	4	+1	3	3	=	ST	3	4	+1	2	3	+1	2	2	=	1	1	=
CR	3	3	=	3	3	=	3	2	-1	3	2	-1	SM	2	3	+1	2	3	+1	2	1	-1	1	1	=
LS	3	4	+1	2	2	=	4	4	=	2	2	=	DK	3	2	-1	1	2	+1	2	2	=	1	1	=
RF	3	2	-1	1	2	+1	3	3	=	2	2	=	FS	2	3	+1	3	2	-1	0	1	+1	2	2	=
IM	3	4	+1	1	1	=	3	2	-1	1	1	=	EJ	3	4	+1	2	2	=	2	3	+1	2	2	=
DD	1	3	+2	3	2	-1	1	1	=	1	1	=	BJ	1	1	=	1	1	=	1	1	=	1	1	=
RE	3	4	+1	2	2	=	3	4	+1	2	2	=	EL	2	3	+1	1	0	-1	2	1	-1	0	1	+1
NJ	1	2	+1	2	1	-1	1	1	=	1	1	=	JG	3	2	-1	3	3	=	4	3	-1	3	3	=
Gains			+10			+3			+3			+1				+5			+3			+3			+2
Losses			-1			-2			-2			-2				-2			-2			-3			-1
Total			+9			+1			+1			-1				+3			+1			=			+1
Ave Gain/loss			+0,9			+0,1			+0,1			-0,1				+0,3			+0,1			0			+0,1
% Gain/ loss			+40,9%			+5,2%			+4,2%			-5,6%				+13%			+5,2%			+0%			+7,1%

TABLE 16

PRAXIS, HANDWORK AND DRAWING

Exp. Group	PRAXIS B	PRAXIS A	PRAXIS Gain Loss	HANDWORK B	HANDWORK A	HANDWORK Gain Loss	DRAWING B	DRAWING A	DRAWING Gain Loss	Control Group	PRAXIS B	PRAXIS A	PRAXIS Gain Loss	HANDWORK B	HANDWORK A	HANDWORK Gain Loss	DRAWING B	DRAWING A	DRAWING Gain Loss
GL	4	3	-1	2	2	=	2	2	=	CJ	4	4	=	2	1	-1	1	1	=
AD	3	2	-1	1	2	+1	0	1	+1	CP	3	4	+1	3	3	=	2	2	=
JW	4	4	=	2	4	+2	2	4	+2	ST	4	4	=	2	2	=	1	2	+1
CR	4	4	=	3	3	=	3	3	=	SM	4	3	-1	2	2	=	2	2	=
LS	4	4	=	2	2	=	1	2	+1	DK	4	4	=	2	2	=	2	2	=
RF	4	4	=	2	2	=	2	1	-1	FS	4	4	=	2	2	=	3	2	-1
IM	4	3	-1	1	1	=	1	1	=	EJ	4	4	=	2	2	=	2	2	=
DD	4	4	=	3	2	-1	2	2	=	BJ	4	3	-1	1	1	=	1	1	=
RE	4	3	-1	2	2	=	2	2	=	EL	4	3	-1	1	1	=	0	0	=
NJ	4	3	-1	1	1	=	2	1	-1	JG	4	4	=	4	3	-1	4	3	-1
Gains			+0			+3			+4				+1			+0			+1
Losses			-5			-1			-2				-3			-2			-2
Total			-5			+2			+2				-2			-2			-1
Ave gain/ loss			-0,5			+0,2			+0,2				-0,2			-0,2			-0,1
% Gain/ Loss			-12,8%			+10,5%			+11,8%				-5,1%			-9,5%			-5,6%

TABLE 17

GRASP

Exp. Group	Grasp cube B	Grasp cube A	Grasp cube Gain Loss	Grasp pellet B	Grasp pellet A	Grasp pellet Gain Loss	Group	Grasp cube B	Grasp cube A	Grasp cube Gain Loss	Grasp pellet B	Grasp pellet A	Grasp pellet Gain Loss
GL	14	13	−1	8	9	+1	CJ	14	16	+2	10	10	=
AD	17	17	=	11	11	=	CP	14	14	=	10	9	−1
JW	17	15	−2	11	12	+1	ST	17	14	−3	20	19	−1
CR	20	20	=	19	19	=	SM	20	20	=	20	20	=
LS	14	14	=	13	12	−1	DK	14	16	+2	11	13	+2
RF	14	17	+3	17	18	+1	FS	14	14	=	10	10	=
IM	15	14	−1	17	10	−7	EJ	14	14	=	12	14	+2
DD	14	14	=	10	10	=	BJ	14	14	=	11	12	+1
RE	20	20	=	19	20	+1	EL	17	16	−1	17	19	+2
NJ	20	20	=	22	22	=	JG	20	18	−2	22	19	−3
Gains			+3			+4				+4			+7
Losses			−4			−8				−6			−5
Total	165	164	−1	147	143	−4		158	156	−2	143	145	+2
Ave & % gain or loss			−0,1 0,6%			−0,4 2,7%				−0,2 1,3%			0,2 1,4%

TABLE 18

MANIPULATION OF THE PELLET

Exp. Group	Pokes Thumb B	Pokes Thumb A	Pokes Thumb Gain Loss	Reaches in B	Reaches in A	Reaches in Gain Loss	Inverts B	Inverts A	Inverts Gain Loss	Pokes with Extended fingers B	Pokes with Extended fingers A	Pokes with Extended fingers Gain Loss	Pokes with other fingers flexed B	Pokes with other fingers flexed A	Pokes with other fingers flexed Gain Loss
GL	0	0	=	1	2	+1	0	0	=	1	2	+1	0	0	=
AD	1	2	+1	2	2	=	2	2	=	2	3	+1	0	1	+1
JW	2	2	=	2	2	=	2	2	=	2	2	=	0	0	=
CR	3	3	=	2	2	=	2	2	=	3	3	=	2	2	=
LS	1	2	+1	2	2	=	2	2	=	2	2	=	0	1	+1
RF	1	2	+1	2	2	=	2	2	=	2	2	=	0	0	=
IM	3	2	−1	2	2	=	0	2	+2	2	2	=	1	0	−1
DD	1	2	+1	2	2	=	0	2	+2	2	2	=	0	0	=
RE	3	3	=	2	2	=	2	2	=	2	2	=	0	0	=
NJ	3	3	=	2	2	=	2	2	=	2	3	+1	0	2	+2
Gains			+4			+1			+4			+3			+4
Losses			−1			=			=			=			−1
Total	18	21	+3	19	20	+1	14	18	+4	20	23	+3	3	6	+3
Ave & % Gains & Losses			0,3 16,7%			0,1 5,3%			0,4 22,2%			0,3 15%			0,3 100%

Control Group	Pokes Thumb B	Pokes Thumb A	Pokes Thumb Gain Loss	Reaches in B	Reaches in A	Reaches in Gain Loss	Inverts B	Inverts A	Inverts Gain Loss	Pokes with Extended fingers B	Pokes with Extended fingers A	Pokes with Extended fingers Gain Loss	Pokes with other fingers flexed B	Pokes with other fingers flexed A	Pokes with other fingers flexed Gain Loss
CJ	1	1	=	2	0	−2	2	2	=	2	0	−2	0	0	=
CP	2	2	=	2	2	=	2	2	=	2	2	=	0	0	=
ST	2	2	=	2	2	=	2	2	=	2	2	=	0	0	=
SM	3	3	=	2	2	=	2	2	=	2	2	=	0	1	+1
DK	2	2	=	2	2	=	2	2	=	2	2	=	0	0	=
FS	2	2	=	2	2	=	2	2	=	2	2	=	0	0	=
EJ	3	1	−2	2	2	=	2	2	=	2	2	=	0	0	=
BJ	2	2	=	2	2	=	2	1	−1	2	2	=	0	0	=
EL	2	2	=	2	2	=	2	2	=	2	2	=	0	0	=
JG	3	2	−1	2	2	=	2	2	=	2	2	=	0	1	+1
Gains			=			=			=			=			+2
Losses			−3			−2			−1			−2			=
Total	22	19	−3	20	18	−2	20	19	−1	20	18	−2	0	2	+2
Ave & % Gains & Losses			−0,3 13,6%			−0,2 10%			−0,1 5%			−0,2 10%			0,2

TABLE 19 GENERALISATION OF SKILLS AND PUSHING AND PULLING OF THE CUBE

Exp. Group	Pushing/Pulling cube			Active Exp.			Generalisation (gn)			Control Group	Pushing/Pulling cube			Active Exp.			Generalisation (gn)		
	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss		B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss
GL	2	2	=	0	0	=	0	0	=	CJ	2	2	=	1	0	-1	1	0	-1
AD	4	4	=	1	1	=	0	1	+1	CP	4	2	-2	1	1	=	1	1	=
JW	4	4	=	1	1	=	1	1	=	ST	4	4	=	1	1	=	2	1	-1
CR	4	4	=	2	2	=	2	2	=	SM	4	4	=	2	2	=	2	2	=
LS	4	4	=	1	1	=	1	1	=	DK	4	4	=	1	1	=	1	1	=
RF	4	4	=	2	1	-1	2	1	-1	FS	4	4	=	1	0	-1	1	1	=
IM	4	2	-2	1	1	=	1	0	-1	EJ	4	2	-2	1	1	=	2	1	-1
DD	4	2	-2	1	1	=	1	1	=	BJ	4	2	-2	1	2	+1	1	1	=
RE	4	4	=	2	2	=	2	2	=	EL	4	2	-2	1	1	=	2	1	-1
NJ	4	4	=	2	2	=	2	2	=	JG	4	4	=	2	2	=	2	2	=
+			0			0			+1				0			+1			0
-			-4			-1			-2				-8			-2			-4
Total	38	34	-4	13	12	-1	12	11	-1		38	30	-8	12	11	-1	15	11	-4
Ave & %			-0,4			-0,1			-0,1				-0,8			-0,1			-0,4
Gain or loss			-10,5%			-7,6%			-8,3%				-21,0%			8,3%			26,7%

TABLE 20

TRANSFER OF CUBE AND PELLET, PLACING AND BILATERAL MANIPULATION OF CUBE

Exp. Group	Transfer cube B	Transfer cube A	Transfer cube Gain Loss	Transfer pellet B	Transfer pellet A	Transfer pellet Gain Loss	Bil. Man. cube B	Bil. Man. cube A	Bil. Man. cube Gain Loss	Placing of cube B	Placing of cube A	Placing of cube Gain Loss
GL	0	0	=	0	0	=	1	1	=	4	4	=
AD	1	1	=	2	4	+2	2	2	=	7	7	=
JW	1	1	=	4	4	=	2	2	=	7	7	=
CR	2	2	=	5	5	=	2	2	=	7	7	=
LS	1	1	=	4	4	=	2	2	=	7	7	=
RF	2	1	-1	5	5	=	2	2	=	7	7	=
IM	2	1	-1	4	2	-2	2	2	=	4	6	+2
DD	1	1	=	2	4	+2	2	2	=	4	7	+3
RE	1	2	+1	5	5	=	2	2	=	7	7	=
NJ	1	2	+1	5	5	=	2	2	=	7	7	=
Gains			+2			+4			0			+5
Losses			-2			-2			0			0
Total	12	12	=	36	38	+2	18	19	=	61	66	+5
Ave & % Gains/ Losses						+0,2 5,6%						+0,5 8,2%

Control Group	Transfer cube B	Transfer cube A	Transfer cube Gain Loss	Transfer pellet B	Transfer pellet A	Transfer pellet Gain Loss	Bil. Man. cube B	Bil. Man. cube A	Bil. Man. cube Gain Loss	Placing of cube B	Placing of cube A	Placing of cube Gain Loss
CJ	0	1	+1	2	2	=	2	1	-1	4	2	-2
CP	1	1	=	4	4	=	2	0	-2	4	2	-2
ST	1	1	=	4	5	+1	2	2	=	4	7	+3
SM	2	2	=	5	5	=	2	2	=	7	7	=
DK	1	1	=	2	4	+2	2	2	=	7	7	=
FS	1	1	=	2	4	+2	2	2	=	7	7	=
EJ	1	1	=	4	5	+1	2	2	=	7	7	=
BJ	1	1	=	4	4	=	2	2	=	6	7	+1
EL	1	1	=	4	4	=	2	2	=	7	7	=
JG	2	2	=	5	5	=	2	2	=	7	7	=
Gains			+1			+6			0			+4
Losses									-3			-4
Total	11	12	+1	36	42	+6	20	17	-3	60	60	=
Ave & % Gains/ Losses			+0,1 9,1%			+0,6 16,7%			-0,3 15%			

TABLE 21

RELEASE

Exp. Group	Throw and drop cube (ml)			Release cube (l)			Release pellet (l)			Control Group	Throw and drop cube (ml)			Release cube (l)			Release pellet (l)		
	B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss		B	A	Gain Loss	B	A	Gain Loss	B	A	Gain Loss
GL	1	1	=	8	14	+6	8	9	+1	CJ	2	1	−1	13	15	+2	15	17	+2
AD	2	3	+1	19	19	=	15	18	+3	CP	2	2	=	16	16	=	21	18	−3
JW	3	3	=	18	18	=	22	18	−4	ST	2	3	+1	17	16	−1	23	25	+2
CR	4	3	−1	22	22	=	25	25	=	SM	3	4	+1	22	19	−3	26	25	−1
LS	2	3	+1	16	15	−1	21	21	=	DK	3	4	+1	18	19	+1	25	21	−4
RF	3	4	+1	16	16	=	25	22	−3	FS	4	4	=	17	18	+1	20	18	−2
IM	2	1	−1	15	15	=	19	21	+2	EJ	3	3	=	16	16	=	23	22	−1
DD	2	2	=	16	16	=	21	16	−5	BJ	3	3	=	16	16	=	21	21	=
RE	3	4	+1	19	22	+3	28	25	−3	EL	3	3	=	17	16	−1	22	23	+1
NJ	4	4	=	22	22	=	28	28	=	JG	4	4	=	19	16	−3	25	25	=
Gains			+4			+9			+6				+3			+4			+5
Losses			−2			−1			−15				−1			−8			−11
Total	26	28	+2	171	179	+8	212	203	−9		29	31	+2	171	167	−4	221	215	−6
Ave + % gain or loss			0,2 7,7%			0,8 4,7%			−0,9 4,2%				0,2 6,9%			−0,4 2,3%			−0,6 2,7%

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