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A neurodevelopmental screening examination for five-year-old children

KATARINA MICHELSSON and ANNELI YLINEN
Children's Hospital, University of Helsinki, Finland

A neurodevelopmental screening examination for five-year-old children is described. The examination takes only 15–20 minutes and tests a wide range of neurodevelopmental abilities. The children receive points for items which they are not able to perform. The sum of the points given is a measure of the child's neurodevelopmental impairment. A group of 52 control children had a mean score of 10.2 points, and the 326 children from child health centres had a mean score of 8.9 points. A group of 647 children who belonged neonatally to a high risk group was also examined. In 609 of these children no clear neurological disease was evident and they received mean score of 18.1 points while the mean score for 38 children with clear handicaps was 73.0. The results show that children who were at risk neonatally had more neurodevelopmental disabilities than children without any neonatal risk factors. Children who received high scores should be referred for more detailed neurological and neuropsychological examinations.

KEY WORDS: Neurodevelopmental screening, five-year-old.

INTRODUCTION

A child with motor disabilities, difficulties with perception and learning, speech problems and behavioural disturbances often fails in school when the expectations surpass his capacity. The child cannot sit quiet and listen to the teacher, he does not learn to read and write, he cannot understand symbols and abstract forms. He has difficulties in sports because he is too clumsy and cannot learn the rules.

A child with all these symptoms is often diagnosed to have minimal brain dysfunction (MBD). Psychical disturbances increase gradually. The child loses his self-confidence and his interest for schoolwork.

To avoid or at least reduce school difficulties an early diagnosis is

necessary, i.e. before school or at school entrance. The age of five has been found in many studies to be a proper age for detecting children with potential school problems (Bax and Whitmore, 1973; Accardo, 1980; Köhler *et al.*, 1979; Whitmore and Bax, 1986).

A screening examination intended for five-year-old children has been developed at the Children's Hospital, University of Helsinki. It is intended to cover a wide range of neurodevelopmental abilities. Children who do not pass the examination might need further check-ups for evaluation of the severity of the symptoms and the need for treatment.

SAMPLE

The series comprised 1,024 children who were divided into four groups. All the children were examined betwen 4 years 10 months and 5 years 3 months of age.

The first group, the *control group*, consisted of 52 children. They were born at term after an uneventful pregnancy and delivery with Apgar scores of 8–9 both at 1 and 5 minutes of age. No pathological symptoms or diseases were observed in the newborn period. The children were examined in 1979 by a child neurologist.

The second group comprised 326 children who consecutively attended child health centres (CHC) in the city of Espoo, Finland, for a check-up in 1980. It is called the *CHC group*. The children were examined by six health centre doctors.

The third group, the *risk group*, included 609 children examined in 1977–79 by a paediatrician or a child neurologist. The children were either born to diabetic mothers or had had one or more of the following risk factors in the newborn period: birth weight $\leqslant$2000g, hyperbilirubinaemia (at least two values $\geqslant$340 mmol/l or blood exchange transfusion performed), hypoglycaemia (at least two values $\leqslant$1.67 mmol/l for full-term and 1.21 mmol/l for prematures), neurological symptoms as convulsions, rigidity, prolonged feeding difficulties, respiratory problems needing respirator care or ventilation by hand, or asphyxia (Apgar scores 6 or less

at 5 min or later). The children have been followed prospectively since birth. The results of the children with severe handicaps were analysed separately.

The fourth group, the *handicap group*, comprised handicapped children who belonged to the risk group and checked in 1976–79 by a paediatrician or child neurologist. Mental retardation and/or cerebral paresis was noted in 27 children. Three children had Down's syndrome. Two children were partially sighted because of retrolental fibroplasia, and one of them was additionally mentally disabled. One child was deaf. Five children had been operated on for hydrocephalys.

METHODS

The neurodevelopmental examination takes about 15–20 minutes if the child cooperates. Figure 1 shows the examination form used. The tasks given test vision, squint, gross and fine motor performance, coordination and balance, involuntary movements, upper motor neuron disturbances, articulation, language skills, perception, concentration and behaviour. Points are given for incomplete and unsuccessful performance. The sum of the points shows the degree of the child's neurodevelopmental impairment. The test has been slightly modified from that by Bax and Whitmore (1973).

The examination itself is easy to perform. However, it demands a thorough knowledge of how to score the performance of the tasks and what a five-year-old child is able to do within the limits of normal development.

Visual acuity. Vision is examined by means of an E-table or, preferably, the Sheridan Gardiner Test of Visual-Acuity (1970).

Squint. Eight points are given if squint is directly apparent to the eye or found by the Hirschberg penlamp test. The investigator holds a pocket flashlight at a distance of about 1 feet from the subject's eye and notes the position of the reflecting light from the child's cornea.

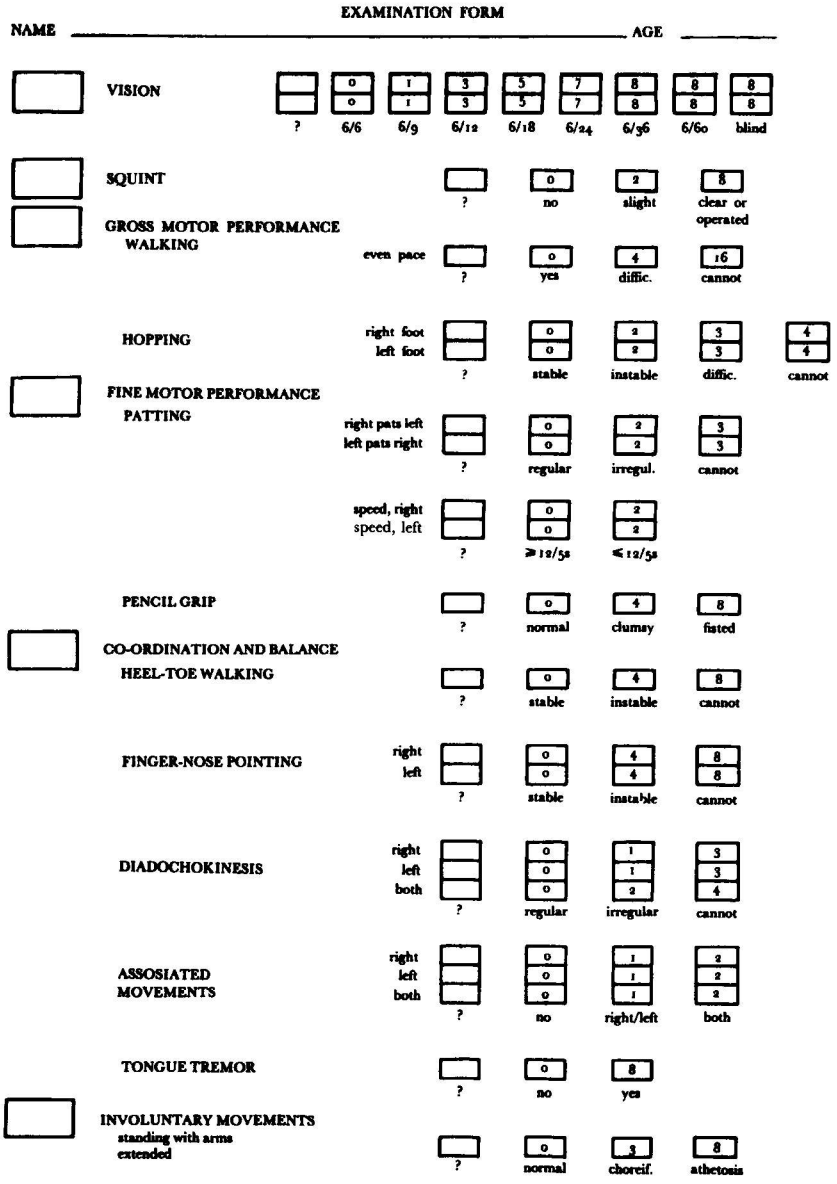
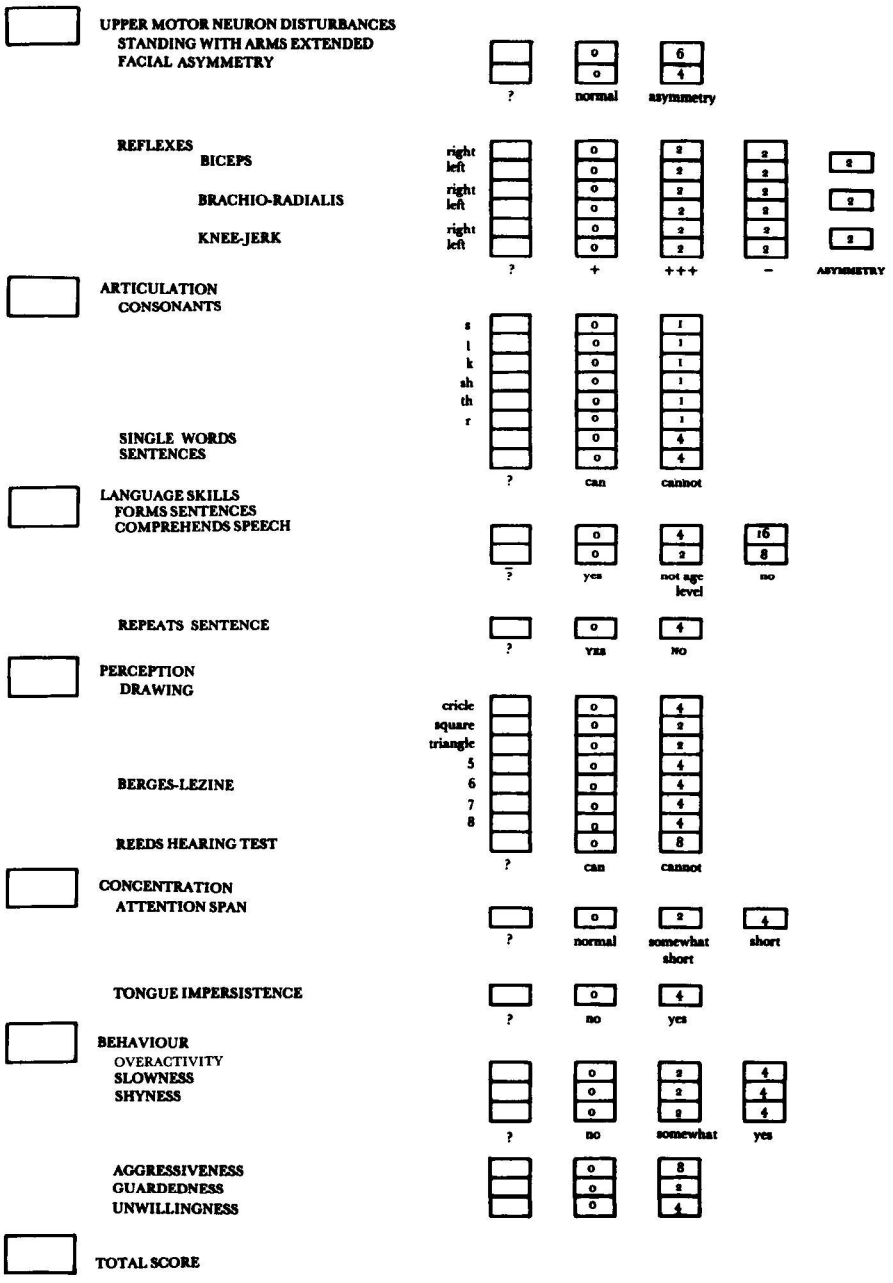


Figure 1. The examination form with points awarded for the test items visible in the rectangles.


UPPER MOTOR NEURON DISTURBANCES
STANDING WITH ARMS EXTENDED
FACIAL ASYMMETRY
? normal asymmetry
REFLEXES
BICEPS
BRACHIO-RADIALIS
KNEE-JERK
right left right left right left
? + +++ − ASYMMETRY
ARTICULATION
CONSONANTS
s l k sh th r
SINGLE WORDS
SENTENCES
? can cannot
LANGUAGE SKILLS
FORMS SENTENCES
COMPREHENDS SPEECH
? yes not age level no
REPEATS SENTENCE
? YES NO
PERCEPTION
DRAWING
cricle square triangle 5 6 7 8
BERGES-LEZINE
REEDS HEARING TEST
? can cannot
CONCENTRATION
ATTENTION SPAN
? normal somewhat short short
TONGUE IMPERSISTENCE
? no yes
BEHAVIOUR
OVERACTIVITY
SLOWNESS
SHYNESS
? no somewhat yes
AGGRESSIVENESS
GUARDEDNESS
UNWILLINGNESS
TOTAL SCORE

Gait. Regularity of gait is controlled by walking the child along a straight line or watching him when he arrives for the examination.

Hopping on one foot. An approved performance requires 5–7 hops on the spot or within a drawn circle. Girls usually hop better than boys. However, both sexes may have difficulties in hopping on the spot.

Patting hands. The child pats the back of one hand with the other one as quickly as possible and both speed and regularity are observed. An approved performance requires at least 12 pats in 5 seconds.

Pencil grip. Five-year-old children usually have a three-finger grip. A fisted grip or a grip high on the pencil (marked as clumsy) is scored incorrect.

Heel-toe walking. Not all five-year-old children can do this perfectly along a straight line and therefore one or two side-steps are allowed.

Finger-nose pointing. The investigator observes whether the child has tremor or other involuntary movements. The best performance is counted, not the first possibly clumsy attempts.

Diadochokinesis. The test is performed first separately on each side and them concomitantly on both sides. The child is asked to keep his upper extremity bent 90 degrees from the elbow along his side with fingers straight ahead. He is also told not to move his elbow and not to press it against the body. The regularity of the supination/pronation movements and all possible associated movements in either upper extremity are observed. As a rule, associated movements can still be seen in five-year-old children.

Standing with arms extended. The child stands with his fingers together, arms stretched out straight forwards, palms downwards, fingers spread and extended and eyes closed. The child is also

asked not to move his fingers. Balance and possible asymmentry, upward or downward movement of the arms, and involuntary movements are observed.

Tongue tremor and impersistence. The child is asked to keep his tongue out and as still as possible for about 20 seconds. Possible tongue tremor is observed. Slight motion of the tongue is not considered abnormal. We also scored motor impersistence, i.e. the child's ability to keep the tongue protruded.

Facial asymmetry. In order to detect possible asymmetry in the facial muscles the child is asked to grimace, close his eyes etc.

Reflexes. Three reflexes (biceps, brachio-radialis and knee-jerk) are examined on both sides and both vivacity and possible asymmetry are observed. Multiple reflexes, the lack of reflexes when the child is fully relaxed and asymmetry are marked as abnormal.

Articulation. The substitution of consonants (s, l, k, sh, th, r) is examined both in single words and in sentences. If a single incorrect consonant is noticed, no points are given for incorrect pronunciation of this consonant in words. The pronunciation of words is scored incorrect if other errors are noticed, as reversals and substitution may occur in sentences although they are normal in single words.

Ability to form sentences. The skill can be ascertained while testing the child but can also be observed by showing pictures which can be discussed.

Repeating consonants. The child can be asked to repeat some simple sentence, for instance "two cats run on the street". This ensures that the child understands instructions. The test sentence is: "The shining kite flies above the trees".

Speech comprehension. This is observed during the whole examination.

Drawing. The child is shown drawings of a circle, square and triangle. Generally the child can copy the triangle and the square but may have difficulties in drawing the triangle.

Imitation of gestures. Different postures of the upper extremities are shown to the child according to items 5–6 and 7–8 by Bergés and Lèzine (1965). No points are given if the child imitates the postures in a form which is not a mirror image.

Reed hearing test. Words are whispered behind the child at a distance of 6 feet from both the right and the left side. The child keeps his hand against the ear not being tested and points at a picture corresponding to the word whispered by the investigator. The pictures are on a table in front of the child. The words are selected to include both high and low frequencies. Bax and Whitmore (1973) used the words "fish, dish, ship and pig". It the child fails in the Picture Screening Test of Hearing (Reed, 1970) it has to be decided if it is because of poor hearing or a deficiency in auditory perception.

Behaviour. Aggressiveness towards the physician can reflect a serious disturbance of behaviour. However, shyness and guardedness do not necessarily mean a behavioural disturbance and may reflect the physician's own ability to co-operate with a five-year-old child. It is also important in evaluating behaviour and concentration ability to notice if the child is tired or hungry at the time of the examination.

Total score. When the total score of the screening examination has been summed attention must be paid to the tasks for which the points were given. For instance, if the points were awarded mostly for vision and squint the child needs to be examined by an ophthalmologist, but if high scores are from many different subgroups it is evident that the child needs more detailed evaluation.

The requisites. Equipment for examining vision, and a penlamp for

squint. Pencil and paper. Cards with drawings of a circle, square and triangle for the Reed hearing test. Reflex hammer.

Order of examination. The test can most conveniently be made in the following order:

—the child standing: gait, heel-toe walking, hopping one foot, sentences, tongue tremor and impersistence, facial asymmetry, squint, imitation of gestures, finger-nose pointing, Reed hearing test.
—the child standing: gait, heel-toe walking, hopping on one foot, standing with arms extended, patting hands, diadochokinesis, vision.
— the child lying: reflexes. They also be examined when the child is sitting if the child is able to relax.

RESULTS

Table 1 shows the results of the neurodevelopmental scores for the four groups. The mean score for the control group was 10.2 ± 6.5 and for the CHC group 8.9 ± 7.2. The scores of the risk group, 18.1 ± 11.6, and the handicap group, 73.0 ± 34.8, were significantly higher compared with the control group and the CHC group ($p < 0.001$, *t*-test, difference between means).

In the control group investigated by a child neurologist (A.Y.) with four years of scoring experience the abilities of children were

Table 1. The mean scores of the screening examination in the four groups of children

Groups of children	*n*	Mean score ± SD
Control group	52	10.2 ± 6.5
CHC group	326	8.9 ± 7.2
Risk group	609	18.1 ± 11.6
Handicap group	38	73.0 ± 34.8

scored as follows: All the children passed the following items without points: gait, tongue tremor, facial asymmetry, forming sentences and tendon reflexes. 1.9% of the children failed (one of 52) in the following items: patting hands, finger-nose pointing, copying a circle and a square, tongue impersistence, an imitation of gestures. Two children, 3.9%, were given points for vision, squint, pencil grip, heel-toe walking, standing with arms extended, word articulation, concentration and guardedness. Four children, 7.7.%, failed in the Reed hearing test and five, 9.6%, were scored for shyness. Nine of the children, 17.3%, could not copy the triangle and 18, i.e. 34.0%, could not hop on one foot. Furthermore, 12 children, 23.1%, could not repeat the sentence, 27 children, 52.8%, could not pronounce the consonants correctly and 17 children were awarded 0–3 points for diadochokinesis, 33 were given 4–7 points, and two children 8 points.

Table 2 shows that in the control group 1.9% of the children had scores of 24–30 and 1.9% had scores of 31 points or more. In the CHC group 1.5% of the children received 24–30 points and 2.1% $\geqslant 31$ points. In the risk group high scores were significantly more frequent, 11.0% had 24–30 points and 13.5% $\geqslant 31$ points. All the children in the handicap group had scores of 24 or more; two children, 5.3%, had scores between 24 and 30 and 36 children, 94.7%, 31 or more.

Table 2. The distribution of the children (%) in the different groups according to scores awarded in the examination

Groups of children	Scores in the screening examination				
	n	<16	17–23	24–29	>31
Control group	52	88.6	7.6	1.9	1.9
CHC group	326	89.3	7.1	1.5	2.1
Risk group	609	54.9	20.6	11.0	13.5
Handicap group	38	0	0	5.3	94.7

Table 3 shows the scores of the risk group children when they were divided according to the risk factor. The highest mean score was noted in children who in the newborn period had had respirator or CPAP care, neurological symptoms, a birth weight ≤2000 g or several risk factors concomitantly.

The difference between the scoring of boys and girls was not statistically significant in the control groups and the CHC group, but was significant in the risk group ($p<0.01$).

Table 3. The mean score of children according to the different neonatal risk factors

Neonatal risk factor	*n*	Mean score + SD
Respiratory difficulties	16	20.0 + 11.0
Neurological symptoms	34	20.0 + 16.4
Birthweight ≤ 2000 g	85	19.1 + 12.5
Diabetes of mother	35	18.8 + 12.0
Asphyxia	95	16.9 + 9.1
Hyperbilirubinaemia	185	16.6 + 9.3
Hypoglycaemia	36	15.4 + 10.2
Septic infections	5	7.8 + 4.5
All with one risk diagnosis	491	17.4 + 10.9
Many risk factors concomitantly	118	21.3 + 13.9
All children	609	18.1 + 11.6

DISCUSSION

The screening examination gives a good idea of a five-year-old child's abilities. It is not meant for children who have handicaps which are already evident without further investigation, such as CP syndromes and obvious mental retardation. However, we included a group of handicapped children in our series to evaluate how these children managed in the test and what their scores were. For less severe handicaps the test is very useful, and we found several cases of slight hemiplegias which had not been detected earlier.

The neurodevelopmental investigation itself is easy to perform but it requires an exact knowledge of how and when to score and what to expect of normally developed five-year-old children. This makes a detailed description of the test procedure necessary, but it also implies some personal experience on the part of those who have not had much pediatric experience in their daily work.

The children did usually perform the test items. In the control group all the children participated in the examination. In the CHC group seven children did not co-operate at all or refused some of the tasks. In the risk group we had only five refusals, but we sometimes spent a lot of time with the child before the particular examination. In the handicap group two children were mentally retarded and did not understand the instructions.

Our control material is standardized for Finnish children; the scores might be somewhat different when the children in other countries are examined. Bax and Whitmore (1973) reported for British children a mean score of 14.9 points. Our control series scored 10.2 points, and the CHC children 8.9 points. A series of five-year-old children from kindergarten in Helsinki were examined by a paediatrician in 1976 and received a mean score of 12.9 (Saarnivaara *et al.*, 1976). The slightly better scoring of the Finnish children compared with the British series can be due partly to the fact that in Finland children as a rule attend kindergarten which imparts training in the kind of abilities which are needed to pass the neurodevelopmental screening test. In addition consonant substitution and repetition of a sentence can score differently depending on the language and the sentence used. Furthermore, Bax and Whitmore (1973) gave scores for undescended testes which we omitted from our investigation.

We found that the risk group scores varied with the neonatal risk factor. If the children had had only one of the risk factors at birth, the mean score was 17.4, but if they had several of the risk factors concomitantly the score was 21.3. It should be noted that we had already excluded from these scores the children with evident handicaps. The results show that neonatal risk factors affect the central nervous system and produce neurodevelopmental disturbances which are detectable at the age of five years.

Bax and Whitmore (1973) found that children with high scores failed in school more often than those with low scores. If the children who will not manage in school are found at the age of five, we can be able to avoid school failure with early treatment and habilitation. Children with high scores are seen more often in the group with neonatal risk, which stresses the importance of careful follow-up of infants at risk. Our results indicate that failure in school can be caused by organic effects to the central nervous system in the neonatal period.

In our followup studies of the risk infants we have noted that children who had had high scores at the age of five did not adjust to the school environment at the age of nine years as well as children who had had low scores (Michelsson and Lindahl, 1986). The results of the prematurely born children in the risk group indicate according to the teachers' statements that 67% were in need of extra supervision compared with 38% in the control series (Michelsson, *et al.*, 1984). The neurodevelopmental screening examinations showed among the prematures a specificity of 80% and a sensitivity of 91%.

We have usually referred children who failed in the screening examination for more detailed neurological and neuropsychological investigations. It is not possible to define precisely when this is necessary, because further examinations depend not only on the total score but also on the items for which points were given. For instance if the child received points only for vision and squint we recommended a visit to an ophthalmologist, but if the scores were from many different items a more detailed examination was considered necessary. Usually all children who received 30 points or more were referred for further investigations; as also the main part of those receiving scores of 24–29.

The abilities of the children who failed in the screening examination were usually to some extent tested further at the first visit. The children were asked to draw a person (Goodenough, 1926), to write their names (Reimer *et al.*, 1975) and to build with cubes and count fingers as recommended by Dubowitz *et al.* (1977).

We asked the children to jump with both feet with their legs together and apart alternatively. We also asked them to walk on

their heels as slight hemiplegias indicate an impaired dorsiflexion of the ankle. The screening examination is good for evaluating neurodevelopmental normality at the age of five years. Children with high scores should be referred for more detailed examinations.

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