TABLE I
Studies on prediction of school failure from preschool screening

Author(s)	*N*	*Screening test*	*Abnormal (%)*	*Interval (yrs)*	*Outcome Criteria of failure*	*%*	*Sensitivity*	*Specificity*	*Predictive value Abnormal*	*Predictive value Normal*
Bax and Whitmore 1973	657	Neurodev.	10	4	School/home problems	?	—	—	0·65	—
Bax and Whitmore 1987	220	Neurodev.	12	5	School problems	16	0·49	—	0·65	—
Camp *et al.* 1977 (Low social class)	65	DDST	26	2	IQ<80 or learning disability	57	0·40	0·93	0·88	0·54
					Learning disability only	38	0·24	0·93	0·75	0·58
Cadman *et al.* 1984	2443	DDST	1·7	1	Learning disability	17	0·06	0·99	0·55	0·84
Sturner *et al.* 1985	346*	DDST	9·2	2	School problems	27	0·29	0·98	0·84	0·79
			25				0·56	0·87	0·61	0·85
Mellbin *et al.* 1982	2600	4-yr screen	10	6	Low learning capacity	12	0·28	—	0·35	—
Drillien and Drummond 1984 (Dundee study)	4004	Neurodev.	13	2	Mild/severe problems	19	0·33	0·89	0·29	0·91
Sell *et al.* 1985 (NICU survivors)	47	McCarthy	?	2	School problems	40	0·78	0·83	0·74	0·86
Michelsson and Lindahl 1984 (Neonatal 'at risk')	164	KAM**	27	4	Learning disability	35	0·42	0·82	0·55	0·72

DDST = Denver Developmental Screening Test: NICU = neonatal intensive care unit.
*Weighted number (N children examined = 113).
**Neurodevelopmental screening test modified from Bax and Whitmore (1973).

TABLE I
Studies on prediction of school failure from preschool screening

Author(s)	*N*	*Screening test*	*Abnormal (%)*	*Interval (yrs)*	*Outcome Criteria of failure*	*%*	*Sensitivity*	*Specificity*	*Predictive value Abnormal*	*Predictive value Normal*
Bax and Whitmore 1973	657	Neurodev.	10	4	School/home problems	?	—	—	0·65	—
Bax and Whitmore 1987	220	Neurodev.	12	5	School problems	16	0·49	—	0·65	—
Camp *et al.* 1977 (Low social class)	65	DDST	26	2	IQ<80 or learning disability	57	0·40	0·93	0·88	0·54
					Learning disability only	38	0·24	0·93	0·75	0·58
Cadman *et al.* 1984	2443	DDST	1·7	1	Learning disability	17	0·06	0·99	0·55	0·84
Sturner *et al.* 1985	346*	DDST	9·2	2	School problems	27	0·29	0·98	0·84	0·79
			25				0·56	0·87	0·61	0·85
Mellbin *et al.* 1982	2600	4-yr screen	10	6	Low learning capacity	12	0·28	—	0·35	—
Drillien and Drummond 1984 (Dundee study)	4004	Neurodev.	13	2	Mild/severe problems	19	0·33	0·89	0·29	0·91
Sell *et al.* 1985 (NICU survivors)	47	McCarthy	?	2	School problems	40	0·78	0·83	0·74	0·86
Michelsson and Lindahl 1984 (Neonatal 'at risk')	164	KAM**	27	4	Learning disability	35	0·42	0·82	0·55	0·72

DDST = Denver Developmental Screening Test: NICU = neonatal intensive care unit.
*Weighted number (N children examined = 113).
**Neurodevelopmental screening test modified from Bax and Whitmore (1973).

detailed description of the series is given in a previous paper (Lindahl *et al.* 1988).

At the age of five years a neurodevelopmental examination originally developed by Bax and Whitmore (1973) was completed. (Some modifications were made for Finnish children.) 12 subscores and the sum of these indicate increasing problems with increasing score (Table III). Over-all performance of the neonatally at-risk children and a comparison group at age five has been published previously (Michelsson *et al.* 1981). The cut-off points for slight (score 24 to 29) and definite (score >29) abnormal neurodevelopmental scores (NDS) were found to be appropriate, so they are also used in the present study. The mean score of children who were examined at five years, but not at nine years (N = 46), was 19·7 (SD 12·5) and the mean score of those examined at five and nine years (N = 350) was 18·7 (SD = 13·2). The difference was not statistically significant. The cut-off point for the operational diagnosis of moderate or marked impairment at age five (NDS ≥24) was exceeded by 87 children (25 per cent). These children were thought to have an increased risk of future school problems. A definitely abnormal performance at age five (NDS ≥30) was found in 56 children (16 per cent).

After the five-year assessment, 146 children (42 per cent) were considered to have problems needing further assessment and/or habilitation. The referrals are detailed in Table IV. The most frequent reason for referral (60 per cent of referrals) was a speech or language problem, including articulation errors. In 62 cases (42 per cent of referrals) the parents either did not agree with or could not carry out the practical arrangements for the proposed intervention. 17 children (5 per cent of the total) were already participating in remedial programmes, either with a speech therapist or at a neuropaediatric rehabilitation centre (Children's Castle Hospital) at the time of the five-year assessment: 14 of these had a five-year NDS >29.

At the age of nine years, when most of the children were in their third school-year, a comprehensive assessment was completed, including a neurodevelop-

TABLE II
Definition of validity and predictive variables

Screening diagnosis	Actual diagnosis: Positive (abnormal)	Actual diagnosis: Negative (normal)	Total
Positive (abnormal)	a Valid positive	b False positive	a + b
Negative (normal)	c False negative	d Valid negative	c + d
Total	a + c	b + d	a + b + c + d

Sensitivity a/a + c; specificity d/b + d; predictive value for positive screening a/a + b; predictive value for negative screening d/c + d.

TABLE III
Scoring of neurodevelopmental examination at age five

Subscore	*Score range*
Visual acuity	0–16
Squint	0–8
Gross motor (two items)	0–24
Fine motor (two items)	0–18
Co-ordination and balance (four items)	0–48
Involuntary movements	0–8
UMN abnormalities (four items)	0–28
Articulation (three items)	0–14
Language (three items)	0–28
Visual and auditory perception (three items)	0–34
Concentration capacity (two items)	0–8
Behavioural problems (five items)	0–22

UMN = upper motor neuron.

TABLE IV
Referrals for further assessment and/or habilitation after five-year neurodevelopmental assessment (N = 350)

Referral to	*N*	*%*
Special kindergarten	12	3·4
Speech therapist	88	25·1
Psychologist	4	1·1
Neuropaediatric rehabilitation centre	42	12·0

Developmental Medicine and Child Neurology, 1988, 30, 723–734

TABLE V
Relationship of social class and five-year performance

Social Class	*Total N*	*Neurodevelopmental score* ≤23 *N*	*%*	24–29 *N*	*%*	≥30 *N*	*%*
I	75	60	80·0	11	14·7	4	5·3
II	93	69	74·2	4	4·3	20	21·5
III	146	112	76·7	12	8·2	22	15·1
IV	36	22	61·1	4	11·1	10	27·8
Total	350	263	75·1	31	8·9	56	16·0

χ^2 16·84, df = 6, p<0·01.

mental examination (Lindahl *et al.* 1988), the Test of Motor Impairment (TMI) (Stott *et al.* 1972, Lindahl 1987), Wechsler Intelligence Scale for Children (WISC, Finnish Edition 1971), seven subtests of the Illinois Test of Psycholinguistic Abilities (ITPA, Finnish Edition) (Kuusinen and Blåfield 1974) and tests of reading and writing (Ruoppila *et al.* 1968, 1969). Peformance in each of the five areas (NEURO, TMI, ITPA, WISC and SCHOOL) was defined as normal or abnormal according to the performance of a comparison group at age nine (for details, see Lindahl *et al.* 1988).

A questionnaire concerning school achievement in reading, writing, mathematics, sports, craft and drawing and need of remedial teaching or a special class was sent to the teachers. School marks for each item were graded from 0 to 2 (good, moderate or poor performance) and were added together to get a sum score, with a maximum of 12 points. A score exceeding six was regarded as definitely abnormal.

Social class was graded according to a four-grade classification by the Helsinki City Authorities (Statistical Office of Helsinki 1961), social class I being the highest. The present study group did not differ significantly from those not included because of missing nine-year examinations. Table V shows the relationships between the four social classes and the three grades of NDS at age five. There is a tendency towards poorer NDS in the lower than in the upper social classes.

Statistical analysis

The BMPD statistical package (Dixon *et al.* 1983) was used. χ^2 tests, with Yates correction when pertinent (BMDP 4F), were used in the analysis of 2 × 2 and 2 × k tables. 2×k tables were also analysed with the linear trend test (BMDP 4F). Mantel-Haenszel statistics were used in comparisons over several 2×2 tables, such as odds ratios in the four social classes. Stepwise multiple linear regression analysis (BMDP 2R) was used to study the explanatory power of the five-year NDS in the nine-year performance. Logarithmic transformations were used to make the variables normally distributed. The programme computes a multiple r^2 (correlation coefficient) value for each variable within the model. It expresses the explanatory power, *i.e.* the proportion of variance of the dependent variable that can be explained by the variables in the model.

Sensitivity, specificity and predictive values for abnormal and normal five-year assessments were calculated, as shown in Table II. If sensitivity is high there will be few false negatives; if specificity is high there will be few false positives. The predictive value for positive (abnormal) results is the proportion of true positives from the screening positives. Similarly, the predictive value for negative (normal) results is the proportion of true negatives from the screening negatives.

Results

Five-year NDS and nine-year outcome

Associations between the five-year NDS and the nine-year outcome variables are presented in Table VI. The proportion of abnormal nine-year performances was from 11 to 22 per cent among the children whose five-year performance was within the normal range (NDS ≤23). 16 to 36 per cent of children in the intermediate group had poor nine-year performance. In the poorest five-year NDS group (score ≥30), problems at age nine were seen in 43 to 68 per cent of the children. The difference was highly significant for each of the nine-year outcome variables (p<0·001).

The importance of social class

Association between five- and nine-year performances within the four social

TABLE VI
Abnormal nine-year examinations grouped by social class and five-year NDS categories

Social class	*NDS category*	*N*	*NEURO* *N*	*%*	*TMI* *N*	*%*	*ITPA* *N*	*%*	*WISC* *N*	*%*	*SCHOOL* *N*	*%*
I-IV	≤23	263	52	20	28	11	48	18	58	22	31	12
	24–29	31	11	36	5	16	9	29	11	36	9	29
	≥30	56	38	68	24	43	28	50	27	48	26	46
	Total	350	101	29	57	16	85	24	96	27	66	18
I	≤23	60	12	20	5	8	2	3	5	8	3	5
	24–29	11	3	27	3	27	0	0	1	9	1	9
	≥30	4	2	50	2	50	3	75	1	25	2	50
	Total	75	17	23	10	13	5	7	7	9	6	8
II	≤23	69	10	15	7	10	9	13	14	20	4	6
	24–29	4	1	25	0	0	0	0	1	25	0	0
	≥30	20	11	55	5	25	7	35	8	40	8	40
	Total	93	22	24	12	13	16	17	23	25	12	13
III	≤23	112	20	18	11	10	29	26	28	25	18	16
	24–29	12	5	42	2	17	6	50	7	58	5	42
	≥30	22	16	73	10	46	10	46	9	41	8	36
	Total	146	41	28	23	16	45	31	44	30	31	21
IV	≤23	22	10	46	5	23	8	36	11	50	6	27
	24–29	4	2	50	0	0	3	75	2	50	3	75
	≥30	10	9	90	7	70	8	80	9	90	8	80
	Total	36	21	58	12	33	19	53	22	61	17	47

classes are presented in Table VI. As shown above, an increasing proportion of poor nine-year performance was nearly always associated with an increasing five-year NDS score. Social class IV children showed the highest proportions of abnormal performance. Most of the associations were statistically significant, but the small numbers make firm conclusions unjustifiable.

The potential confounding effect of social class on associations between the five-year NDS (with two cut-off scores, ≥24 and ≥30) and the nine-year outcome variables were studied with Mantel-Haenszel statistics (Table VII). No significant differences were found between the odds ratios in the four social classes, in spite of the impression of poorer performance among the lower social classes shown in Table VI. The Mantel-Haenszel (combined for the four social classes) shows the risk of abnormal nine-year outcome when the five-year NDS was abnormal (Table VII). A significantly increased risk was found for every nine-year subscore. The highest risk was associated with poor NEURO performance, which can be explained by the similar character of the NDS and NEURO items. A five-fold risk of markedly poor school progress was seen in both grades of abnormal NDS.

Sensitivity, specificity and predictive power of NDS

Another way of looking at the five- and nine-year performance associations is to calculate the predictive parameters, *i.e.* sensitivity, specificity, and positive and negative predictive values (see Table II). Both degrees of abnormality in the five-year NDS and the abnormal nine-year outcome measures were used (Table VIII). In addition, a sum of the five dichotomized outcome scores, called 9y TOTAL, was used to analyse the nine-year performance as a whole. Each of the five subscores was marked 0 for normal and 1 for abnormal performance, giving a maximum score of 5 for the 9y TOTAL. An occurrence of two or more problems was regarded as an abnormal 9y TOTAL. 57 children (22 per cent) from the normal

TABLE VII

Prediction of abnormal nine-year outcome with two abnormality grades of five-year NDS, with effects of social class taken into account†

	NEURO	TMI	ITPA	WISC	SCHOOL
Five-year NDS ≥24					
Test for homogeneity df=3, χ^2 (p)	3·04 (NS)	1·17 (NS)	1·89 (NS)	0·46 (NS)	2·20 (NS)
Mantel-Haenszel risk	5·0	3·9	3·3	2·6	5·0
χ^2 (p)	36·74***	20·19***	16·41***	10·76***	28·21***
Five-year NDS ≥30					
Test for homogeneity df=3, χ^2 (p)	0·94 (NS)	1·49 (NS)	7·59 (NS)	1·93 (NS)	4·71 (NS)
Mantel-Haenszel risk	8·2	6·0	3·6	2·6	5·1
χ^2 (p)	43·09***	28·96***	16·41***	7·91**	24·69***

***p<0·001, **p<0·01.

†Test of homogeneity between odds ratios in four social classes and Mantel-Haenszel statistics for combined group (computed from figures in Table VI).

TABLE VIII

Sensitivity, specificity and predictive values for positive and negative five-year assessments versus normal and abnormal nine-year assessments

Parameter	NEURO	TMI	ITPA	WISC	SCHOOL
NDS ≥24					
Sensitivity	0·48	0·51	0·44	0·40	0·53
Specificity	0·85	0·80	0·81	0·81	0·82
Predictive +	0·56	0·33	0·43	0·44	0·40
Predictive −	0·80	0·89	0·82	0·78	0·88
NDS ≥30					
Sensitivity	0·38	0·42	0·33	0·28	0·39
Specificity	0·93	0·89	0·89	0·89	0·89
Predictive +	0·68	0·43	0·50	0·48	0·46
Predictive −	0·79	0·89	0·81	0·77	0·86

TABLE IX

Five-year NDS and school marks according to poorest score (N=311)

NDS	Reading N	Reading %	Writing N	Writing %	Mathematics N	Mathematics %	Craft N	Craft %	Sports N	Sports %	Drawing N	Drawing %	Total† N	Total† %
≤23	23	10	28	12	18	8	16	7	8	4	15	7	41	18
24–29	6	23*	8	31**	4	15**	5	20***	2	8***	6	23**	8	32**
≥30	10	19	14	27	12	23	13	26	8	16	10	19	20	40
Total	39	13	50	16	34	11	34	11	18	6	31	10	69	23

†Indicates number of children with school marks >5 (scores from 0 to 2 given).
Linear trend test: *p<0·05, **p<0·01, ***p<0·001.

NDS group, 13 (42 per cent) from the intermediate NDS group and 39 (70 per cent) from the poorest NDS group had two or more problems (χ^2 51·39, df 2, $p<0\cdot001$).

Specificity and predictive values for a negative (normal) five-year NDS were fairly high (80 to 93 and 77 to 89 per cent, respectively). Sensitivity was approximately 40 to 50 per cent for the lower NDS cut-off point and approximately 30 to 40 per cent for the higher NDS cut-off point. This means that 50 to 70 per cent of children with problems at age nine might have been missed in the five-year classification. The fact that the lowest sensitivity values were seen for the WISC cognitive test could be regarded as evidence that the NDS is not a measure of intelligence. The predictive value for an abnormal NDS was from 33 to 56 per cent for the lower NDS cut-off point and from 43 to 68 per cent in the poorest NDS group. This means that about half of the children with a NDS identifying 25 per cent of the five-year-olds did not have any marked problems at age nine. The higher NDS cut-off point, which identified 16 per cent of the five-year-olds, proved to be a better predictor.

The total nine-year score (9y TOTAL) did not seem to have any marked advantage in prediction compared with the subscores at age nine. The neurodevelopmental assessment (NEURO) at age nine seemed to be the most efficient reference for the NDS. Of the 101 children with abnormal NEURO at nine, 75 per cent had at least one other problem.

NDS and school problems

School marks from the teachers' questionnaires were available for 311 nine-year-olds. Table IX shows the distribution of the children with the poorest school marks according to their five-year NDS. A poor NDS was significantly associated with poor school marks. Two to four times more children with an abnormal NDS had poor school marks compared with those with a NDS ≤23.

Associations between NDS and special school arrangements are shown in Table X. Half the children attending a special class, who had had to repeat a year, or who started school later than usual had a NDS ≥30. The NDS distribution for children who needed extra help at school is shown in Table XI. 45 per cent of these children did not have any extra tutoring, but 36 per cent were given extra supervision by their teachers outside normal school hours. There was no significant difference between the three NDS grades. This kind of support is easily available in Finland if, for example, the child has been ill or for some other reason had temporarily fallen behind the rest of the class. Remedial education by a specialized teacher and speech therapy were given significantly more often to children with a NDS score of ≥24 than to children with a normal NDS (Table XI).

TABLE X
Five-year NDS and special school arrangements at nine years

NDS	*N*	*Special school arrangement* *N*	*%*
≤23	233	9	4
24-29	26	4	15
≥30	52	14	27

Linear trend test, $p<0\cdot001$.

The problem of false negatives

The reasons why a considerable number of children had been missclassified, who proved to be false negatives, could not be fully clarified. Of the 263 children with a normal five-year NDS (<24), 142 (54 per cent) had no problems at nine years. 64 children (24 per cent) had one problem, 32 (12 per cent) had two problems, 16 (6 per cent) had three problems and nine (3 per cent) had four or five problems at age nine. 21 of the 64 children with only one problem at age nine failed in the NEURO subtest and seven had poor school progress. 10 children had both NEURO and SCHOOL problems (18 per cent of those with a normal NDS and at least two nine-year problems). 19 children had a poor WISC performance alone (30 per cent of those with a normal NDS and one nine-year problem), and 39 children had a poor WISC and some other nine-year problem (68 per cent of those with a

Developmental Medicine and Child Neurology, 1988, 30, 723–734

TABLE XI

Five-year NDS and special tutoring given at nine years (%)

NDS	*N*	*No extra tutoring*	*Extra tutoring by own teacher*	*Remedial teaching*	*Speech therapy*
≤23	233	49	35	14	20
24-29	26	38	31	27**	35**
≥30	52	29	44	27	37
Total	311	45	36	17	24

Linear trend test, no extra tutoring tested against extra tutoring by own teacher, remedial teaching, and speech therapist.
**$p<0·01$.

TABLE XII

Associations between five-year NDS and nine-year outcome scores

NDS subscore	*5yr NDS* r^2	*NEURO* r^2	*TMI* r^2	*ITPA* r^2	*WISC* r^2	*SCHOOL* r^2
Visual acuity	0·08	—	0·01	—	—	—
Squint	0·02	0·01	—	—	—	—
Gross motor	0·03	0·03	0·04	—	—	—
Fine motor	0·03	—	—	—	—	—
Co-ordination/balance	0·19	0·02	0·02	—	—	0·01
Involuntary movements	0·01	—	—	—	—	—
UMN abnormalities	0·01	—	—	—	—	0·01
Articulation	0·02	0·04	—	0·02	0·03	0·01
Language	0·03	0·02	—	0·09	0·01	0·06
Perception	0·45	0·14	0·09	0·05	0·13	0·11
Concentration	0·02	—	—	—	—	—
Behaviour problems	0·10	—	—	—	—	—
Multiple r^2	0·99	0·26	0·16	0·16	0·17	0·21

UMN = upper motor neuron.

normal NDS and multiple nine-year problems). In all, 48 per cent of children with a normal NDS and some problem at nine years had a poor WISC performance.

These findings could partly explain the problem of false negatives. The results above also show that of all the nine-year measurements, the lowest association was between NDS and WISC. However, the proportion of children with a poor WISC among those with a normal NDS was only marginally greater (statistically non-significant) than that of children with poor performance in other nine-year examinations.

NDS and nine-year performance

Associations between the total five-year NDS and its subscores (see Table III) and the nine-year problems were also studied with stepwise multiple linear regression analysis, to examine whether it would be more effective to use the continuous scores of both five- and nine-year examinations instead of groups created according to the somewhat artificial cut-off points described earlier. A summary of these analyses is presented in Table XII, with the increase in multiple r^2 (explanatory power) for each subscore. The contribution of the NDS subscores to the total NDS is shown in the first column. Together, the co-ordination/balance and perception subscores explained 64 per cent of the NDS variance. The multiple r^2 values for the majority of the subscores are very low, indicating that they could explain only a small part of the variance of NDS.

Considering nine-year outcome scores,

the gross motor, co-ordination/balance and perception NDS subscores seemed to be of importance in the NEURO and TMI results. For ITPA, WISC and SCHOOL, the NDS perception, language and articulation subscores had the highest r^2 values. The total variance of the nine-year subscores explained by the five-year subscores was about 20 per cent (Table XII). The perception subscore had the highest explanatory power in the total nine-year score, the multiple r^2 also exceeding those seen in the nine-year subscores.

Usefulness of a reduced NDS in prediction
In order to study the possibility of improving the predictive power of the NDS, a reduced score of the five NDS subscores with the highest explanatory power values (Table XII), *i.e.* gross motor, co-ordination and balance, articulation, speech/language and auditory/visual perception, was computed. Cut-off points for mildly and definitely abnormal scores were defined. A reduced score (NDS-R) of 17 or more was exceeded by 27 per cent of all children, and a score of 19 of more by 18 per cent. When these cut-off points were used in the calculation of sensitivity, specificity and predictive power for abnormal or normal results, the figures were about the same as those presented in Table VIII.

Discussion

Attempts at preschool identification of children with later learning problems have been strongly criticised (Cadman *et al.* 1984*b*). Keogh and Becker (1973) state that identificiation of at-risk children is more of an hypothesis than a confirmation, as the problems that are looked for, such as learning disabilities, have not yet developed. It is not at all clear whether the functions measured in the preschool period are those involved in the learning processes of later years (Lindsay and Wedell 1982). Tests used in most studies result in false categorisation of a considerable proportion of children. This is potentially harmful, especially for parents whose children turn out to be false positives. Similarly, many families are surprised when school problems emerge, despite an acceptable preschool performance. If a prediction of future disturbances is made, resources must be available for intervention, or at least for discussions and advice. However, the families and children most in need of surveillance and support are the least likely to use the facilities (Zinkin and Cox 1976).

The results of different preschool screening studies are difficult to compare for several reasons. The validity and predictive variables for the test used often are not reported and cannot be calculated from the available data. Correlation coefficients are not a measure of validity, although they may be highly significant in large series, as in the present study. Neither do proportions of 'hits and misses' provide exact information as to the validity of the instrument. In previous studies, the tests used in prediction and the outcome measures are different in nature, and the ages of the children examined and the prevalence of the expected disturbance vary (see Table I). Also, social and familial factors often are not taken into account or are not reported. In the study of Camp *et al.* (1977) with the Denver Developmental Screening Test, for instance, all the children came from a socially disadvantaged area. The prevalences of intellectual impairment and learning problems were very high, as was the predictive value for a positive screening result. However, 42 to 46 per cent of children with normal screening results developed school problems later. In the study by Cadman *et al.* (1984*a*) of a large population of unselected children, sensitivity was extremely low and only about half the children screened as positive proved to have problems at school.

In Sweden, where the standard of living and health-care facilities are comparable with those in Finland, health screening at the age of four years was found to be disappointing, both for general health problems and for prediction of school progress at the age of 10 years (Mellbin *et al.* 1982; see Table I). Low social class was found to be an important predictor. Those authors stress the importance of environmental screening and the identification of children with socio-emotional problems.

In a series of survivors of neonatal

Developmental Medicine and Child Neurology, 1988, 30, 723–734

intensive care, the predictive power of the McCarthy Scales was found to be satisfactory (Sell *et al.* 1985; see Table I). However, the McCarthy Scales should not be regarded as a screening test.

Whitmore and Bax (1986) recently published a modification of their earlier test (Bax and Whitmore 1973), in which more attention is paid to the assessment of language and behavioural aspects. The full NDS at five years was found to be the best predictor of learning difficulties at age 10, but the subscores also were found to be reliable predictors of future problems (Bax and Whitmore 1987), as was also seen in the present study. Bax and Whitmore state, however, that clinical assessment by an experienced doctor is more reliable than a test score, and that test scores should not be used for prediction. They also question whether prediction was necessary in their setting—a school-entrant medical examination. Predictive validity becomes more important, however, if the assessment is made one or two years before school entry, when at least some children could benefit from kindergarten, remedial programmes or a consultation with a neuropsychologist or a speech or occupational therapist.

In the present study, the expected prevalence of disturbance was higher than in the normal population. Abnormal performance at the nine-year examinations was judged in relation to a comparison group (Lindahl *et al.* 1988). According to Finnish school statistics for school classes I to VI, 10 per cent of children receive remedial education, 7 per cent speech therapy and about 2 per cent are in a special class (Finland: Central Statistical Office 1981).

In the present study, the capacity of the NDS to predict school problems was less than expected. This may have been because the criteria for abnormal school performance might not have been sensitive enough for the measures used. However, a poor NDS did significantly increase the risk of poor school performance.

The validity and predictive values, though far from optimal, were acceptable in comparison with earlier studies. In the study of Bax and Whitmore (1987), when the revised version of the five-year NDS was used, sensitivity values were 50 to 60 per cent and the predictive value for abnormal performance was 40 to 65 per cent, depending on the cut-off points used. Sensitivity could be increased only at the cost of decreasing the predictive value for abnormal performance, *i.e.* increasing the proportion of false positives. Those authors stress, however, that their school-entrant examination is not designed to give a prediction.

Our results seem to justify the use of a reduced NDS if prediction of the problems described above is regarded as necessary, and if the predictive parameters are considered good enough. A very important goal in this kind of study would be to improve the instruments and criteria with which the outcome is defined.

An effect of social class was seen in the present study, especially in the five-year performance (see Table V). However, low social class did not increase the risk of school-age problems predicted from five to nine years. The effects of socio-economic factors in the long-term prognosis are important, however, as has been shown in our previous report (Lindahl *et al.* 1988).

The preschool screening test used in our study proved to be as efficient as most of those reported earlier. There is still room for improvement, however, especially as to the predictive value of an abnormal screening result. The newly revised version of the test (Whitmore and Bax 1986, Bax and Whitmore 1987) seems to have achieved this goal. However, the test results should not be the only criteria for prediction, if prediction is considered necessary. The clinical judgement of an experienced doctor, based on a comprehensive assessment of the child and the child's background, should be the starting point for further evaluations, as well as for supporting and remedial measures.

Accepted for publication 7th January 1988.

Acknowledgements
This study was financially supported by the Foundation for Paediatric Research, the Association for Life Insurance Companies in Finland and the Signe and Ane Gyllenberg Foundation, Finland. We are grateful to Associate Professor Seppo Sarna, Ph.D. for his valuable statistical advice, to Mrs. Hillevi Ahonen for her work in the practical

arrangements of the study and to Anneli Ylinen, M.D. for her contribution to both the five- and nine-year studies.

Authors' Appointments
*Elina Lindahl, M.D.;
Katarina Michelsson, M.D., Administrative Assistant Chief;
Märta Donner, M.D., former Senior Lecturer;
II Department of Pediatrics, Children's Hospital, University of Helsinki, 00290 Helsinki 29, Finland.

**Correspondence to first author* at Children's Castle Hospital, Lastenlinnantie 2, 00250 Helsinki, Finland.

SUMMARY
A group of 350 children who had had neonatal developmental risk-factors were assessed at the age of five years with a neurodevelopmental examination. At nine years they were assessed again for neuropaediatric, motor, psycholinguistic, cognitive and school-achievement problems. (Children with major handicaps were excluded.) Poor performance at age five was significantly associated with failure in the nine-year examinations and with school problems. Sensitivity of the five-year neurodevelopmental examination in predicting problems at nine years was 0·30 to 0·50, and its predictive value for an abnormal performance was 0·30 to 0·60. Predictively, the neurodevelopmental examination was accurate in defining children without later problems, but less satisfactory in defining those who did develop problems. Multiple linear regression analyses between the neurodevelopmental examination and the scores at nine years revealed low explanatory power. A shortened neurodevelopmental examination, based on the best predictors, seemed to be as efficient as the full examination.

RÉSUMÉ
Prédiction des problèmes scolaires précoces par un examen neurodéveloppemental préscolaire des enfants à risque néo-natal
Un groupe de 350 enfants ayant présenté des facteurs néo-nataux de risques développementaux ont été évalués à l'âge de cinq ans à partir d'un examen neurodéveloppemental. Ils ont été examinés à nouveau à l'âge de neuf ans sur des problèmes neuropédiatriques, moteurs, psycholinguistiques, cognitifs et d'évolution scolaire. (Les enfants présentant des handicaps majeurs ont été éliminés). Une performance médiocre à l'âge de cinq ans était significativement associée avec des échecs aux examens de neuf ans et des problèmes scolaires. La sensibilité de l'examen neurodéveloppemental de cinq ans pour prévoir des problèmes à neuf ans était de 0·30 à 0·50, et sa valeur prédictive pour une performance anormale était de 0·30 à 0·60. Prospectivement, l'examen neurodéveloppemental a été précis pour définir les enfants sans problèmes ultérieurs, mais moins satisfaisant pour prévoir ceux qui eurent des problèmes. Une analyse linéaire de régression multiple entre l'examen neurodéveloppemental et les scores à neuf ans n'a pas révélé un fort pouvoir explicatif. Un examen neurodéveloppemental rapide a semblé aussi efficace qu'un examen complet.

ZUSAMMENFASSUNG
Voraussage von Problemen im frühen Schulalter durch eine Untersuchung der neurologischen Entwicklung in der Vorschule bei neonatalen Risikokindern
Eine Gruppe von 350 Kindern mit neonatalen Risikofaktoren wurde im Alter von fünf Jahren anhand einer neurologischen Entwicklungsuntersuchung beurteilt. Mit neun Jahren wurden sie erneut auf neuropädiatrische, motorische, psycholinguistische, kognitive und Schulleistungs-Probleme untersucht. (Kinder mit gravierenden Störungen wurden ausgeschlossen.) Schlechte Untersuchungsergebnbisse im Alter von fünf Jahren korrelierten signifikant mit schlechten Ergebnissen bei den Untersuchungen mit neun Jahren und mit Schulproblemen. Die Sensitivität der neurologischen Entwicklungsuntersuchung mit fünf Jahren, Probleme im Alter von neun Jahren vorrauszusagen, betrug 0·30-0·50 und ihr prognostischer Wert für abnormes Verhalten 0·30-0·60. Die neurologische Entwicklungsuntersuchung gab eine genaue Voraussage für Kinder ohne spätere Probleme, aber eine weniger befriedigende für die, die später Probleme entwickelten. Multiple lineare Regressionsanalysen zwischen der neurologischen Entwicklungsuntersuchung und den Scores mit neun Jahren ergaben keine wesentlichen Aufschlüsse. Eine gekürzte neurologische Entwicklungsuntersuchung mit den besten Parametern schien genauso effizient zu sein wie die ganze Untersuchung.

RESUMEN
Predicción de problemas precoces en la edad escolar a partir del examen del neurodesarrollo preescolar en niños con riesgo neonatal
Un grupo de 350 niños que había tenido factores de riesgo de desarrollo neonatal fueron evaluados a la edad de cinco años con un examen neuroevolutivo. A los nueve años fueron evaluados neuvamente en busca de problemas neuropediátricos motores, psicolinguísticos, cognitivos y de éxito escolar. (Se excluyeron los niños con minusvalía grave.) La pobre realización a la edad de cinco años estaba significativamente asociada con el fracaso en los examenes a los nueve años y con problemas escolares. La sensibilidad de los examenes neurovolutivos a los cinco años, para predecir problemas a los nueve fué de 0·30 a 0·50 y su valor predictivo para una realización anormal fué de 0·30 a 0·60. Predictivamente, el examen neuroevolutivo fué preciso en definir niños sin problemas

Developmental Medicine and Child Neurology, 1988, 30, 723–734

posteriores, pero menos satisfactorio para definir aquellos que los tendrian más tarde. El análisis múltiple lineal de regresión entre el examen neuroevolutivo y los puntajes a los nueve años, reveló un bajo poder explicativo. Un examen neuroevolutivo abreviado basado en los mejores factores predictivos, parece que fué tan efectivo como un examen completo.

References

Bax, M., Whitmore, K. (1973) 'Neurodevelopmental screening in the school-entrant medical examination.' *Lancet*, **2**, 368–370.

— — (1987) 'The medical examination of children on entry to school. The results and use of neurodevelopmental assessment.' *Developmental Medicine and Child Neurology*, **29**, 40–55.

Cadman, D., Chambers, L. W., Walter, S. D., Feldman, W., Smith, K., Ferguson, R. (1984*a*) 'The usefulness of the Denver Developmental Screening Test to predict kindergarten problems in a general community population.' *American Journal of Public Health*, **74**, 1093–1097.

— — Feldman, W., Sackett, D. (1984*b*) 'Assessing the effectiveness of community screening programs.' *Journal of the American Medical Association*, **251**, 1580–1585.

Camp, B. W., van Doorninck, W. J., Frankenburg, W. K., Lampe, K. M. (1977) 'Preschool developmental testing in prediction of school problems.' *Clinical Pediatrics*, **16**, 257–263.

Dixon, W. J., Brown, M. D., Engelman, L., Frane, J. W., Hill, M. A., Jennrich, R. I., Toporek, J. D. (Eds.) (1983) *BMPD Statistical Software*. Los Angeles: University of California Press.

Drillien, C. M., Drummond, M. (1983) *Development Screening and the Child with Special Needs. Clinics in Developmental Medicine, No. 86*. London: S.I.M.P. with Heinemann Medical: Philadelphia: Lippincott.

Finland: Central Statistical Office (1981) *Statistical Report KO 1981:7* (Finnish). Helsinki: State Printing Office.

Keogh, B. K., Becker, L. D. (1973) 'Early detection of learning problems: questions, cautions and guidelines.' *Exceptional Children*, **40**, 5–11.

Kuusinen, L., Blåfield, L. (1974) *Illinois Test of Psycholinguistic Abilities, Finnish Edition. Institute of Educational Research, Report No. 234*. Jyväskylä: University of Jyväskylä.

Lindahl, E. (1987) 'Motor performance of neonatal risk and non-risk children at early school-age.' *Acta Paediatrica Scandinavica*, **76**, 809–817.

— Michelsson, K., Helenius, M., Parre, M. (1988) 'Neonatal risk factors and later neurodevelopmental disturbance.' *Developmental Medicine and Child Neurology*, **30**, 571–589.

Lindsay, G. A., Wedell, K. (1982) 'The early identification of educationally 'at risk' children revisited.' *Journal of Learning Disabilities*, **15**, 212–217.

Mellbin, T., Sundelin, C., Vuille, J.-C. (1982) *From Four Years to Ten. Health and Adjustment from Play Period to Preadolescence* (Swedish). Stockholm: National Board of Social Welfare.

Michelsson, K., Lindahl, E. (1984) 'Skolframgång hos nioåringar för vilka det föreligger perinatala riskfaktorer.' *Finska Läkaresällskapets Handlingar*, **144**, 136–141.

— Ylinen, A., Donner, M. (1981) 'Neurodevelopmental screening at five years of children who were at risk neonatally.' *Developmental Medicine and Child Neurology*, **23**, 427–433.

Rouppila, I., Röman, K., Västi, M. (1968) *Diagnostic Reading Tests for Grades II and III in the Elementary School* (Finnish). *Institute of Educational Research, Report No. 41*. Jyväskylä: University of Jyväskylä.

— — — (1969) *Diagnostic Writing Tests for Grades II and III in the Elementary School* (Finnish). *Institute of Educational Research, Report No. 50*. Jyväskylä: University of Jyväskylä.

Sell, E. J., Gaines, J. A., Gluckman, C., Williams, E. (1985) 'Early identification of learning problems in neonatal intensive care graduates.' *American Journal of Diseases of Children*, **139**, 460–463.

Statistical Office of Helsinki (1961) *Social Grouping* (Finnish and Swedish). Helsinki: Statistical Office.

Stott, D. H., Moyes, F. A., Henderson, S. A. (1972) *A Test of Motor Impairment*. Guelph, Ontario: Brook Educational.

Sturner, R. A., Green, J. A., Funk, S. G. (1985) 'Preschool Denver Developmental Screening Test as a predictor of later school problems.' *Journal of Pediatrics*, **107**, 615–621.

Wechsler Intelligence Scale for Children, Finnish Edition (1971). Helsinki: Psykologien Kustannus, University of Helsinki.

Whitmore, K., Bax, M. (1986) 'The school entry medical examination.' *Archives of Disease in Childhood*, **61**, 807–817.

Zinkin, P. M., Cox, C. A. (1976) 'Child health clinics and inverse care laws: evidence from longitudinal study of 1878 pre-school children.' *British Medical Journal*, **2**, 411–413.