
Predictors of cognitive performance:
age, education, and intelligence.

A. Gade, E. Lykke Mortensen, H. Udesen & A. Jønsson
Dept. of Neurology, Rigshospitalet, Copenhagen

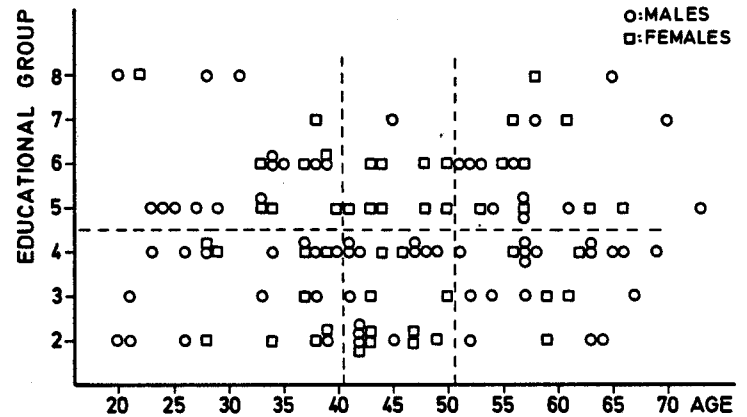
A. GADE (Copenhagen, Denmark), E. LYKKE MORTENSEN, H. UDESEN, and A. JØNS-SON. Predictors of Cognitive Performance: Age, Education, and Intelligence. We studied 120 CNS-normal hospitalized subjects aged 20-73 years with an extensive battery of cognitive tests. Results from our Basic Battery (BB) of tests were factor analyzed and converted to *T* scores. Composite factor scores were subjected to multiple regression analyses to identify predictors. Age accounted for only 15% of the variance in the mean total BB performance. Education accounted for 30%. Inclusion of the nonlinearity of the age-influence and the interaction of age and education added 11%. Finally, a measure of verbal IQ brought the explained mean BB variance up to 80%. Unaccounted variance was somewhat greater in other factor scores and individual tests. Application of the regression equations to groups of normal subjects and neurological patients have indicated the validity of this approach. Use of the formula in addition to profile analysis of test performance may increase diagnostic precision.
Supported by the Danish Medical Research Council

1. Research aim
 - A) To develop methods that can objectively measure and describe impairment in cognitive functions with the greatest accuracy possible.
 - B) To compare the validity of different methods.

2. Study purpose
 - A) To examine the relative influence of many background variables on the variance of results in neuropsychological tests in normal subjects.
 - B) To apply equations from regression analyses on individual subjects to evaluate the accuracy, sensitivity and validity of an approach with comparisons of observed and predicted scores in various groups.

methods

5. Fig. 1. Distribution of 120 normal subjects over age and education.



3. Subjects

120 CNS-normal hospitalized subjects were rigorously selected for health except lower limb or peripheral nerve injury and tested individually. The social class composition of our group approximates that of the Danish population. The educational level (school level + occupational level) was held constant over age groups (fig. 1).

For comparison we have examined various diagnostic groups of neurological patients.

4. Table 1. Background variables in three age groups. (percentages).

AGE GROUP	SEX		SCHOOL LEVEL			OCCUPATIONAL LEVEL					SOCIAL GROUP (SF1)				
	M	F	1	2	3	1	2	3	4	5	1	2	3	4	5
20 - 40 (N:45)	62	38	42	42	16	18	16	40	18	9	4	7	20	33	29
41 - 50 (N:32)	41	59	69	28	3	31	13	38	16	3	3	6	28	25	38
51 - 73 (N:43)	67	33	49	35	16	16	12	53	14	5	14	7	35	26	19
TOTAL (N:120)	58	42	52	36	13	21	13	44	16	6	8	7	28	28	28

*) ALL DIFFERENCES ARE NON-SIGNIFICANT.

6. Test Battery.

Most of the tests used may be found in fig. 2. Our test battery has deliberately been designed to include three general types of tests:

- a) tests that were chosen to principally reflect the premorbid level (verbal Wechsler subtests, DART),
- b) tests known to be sensitive to the effects of diffuse cerebral lesions, and
- c) tests that - although perhaps not particularly sensitive to the impairment in dementia - might be useful in the examination of patients with specific cognitive deficits.

The Basic Battery (BB) tests are those which we routinely use as a minimum in the examination of referred patients suspected of intellectual impairment.

Composite scores from BB tests are used in this communication. These scores are based on the results of factor analysis of results from our 120 normal subjects (table 2).

7. Table 2.

BB subtest loadings of .50 or more following rotation.

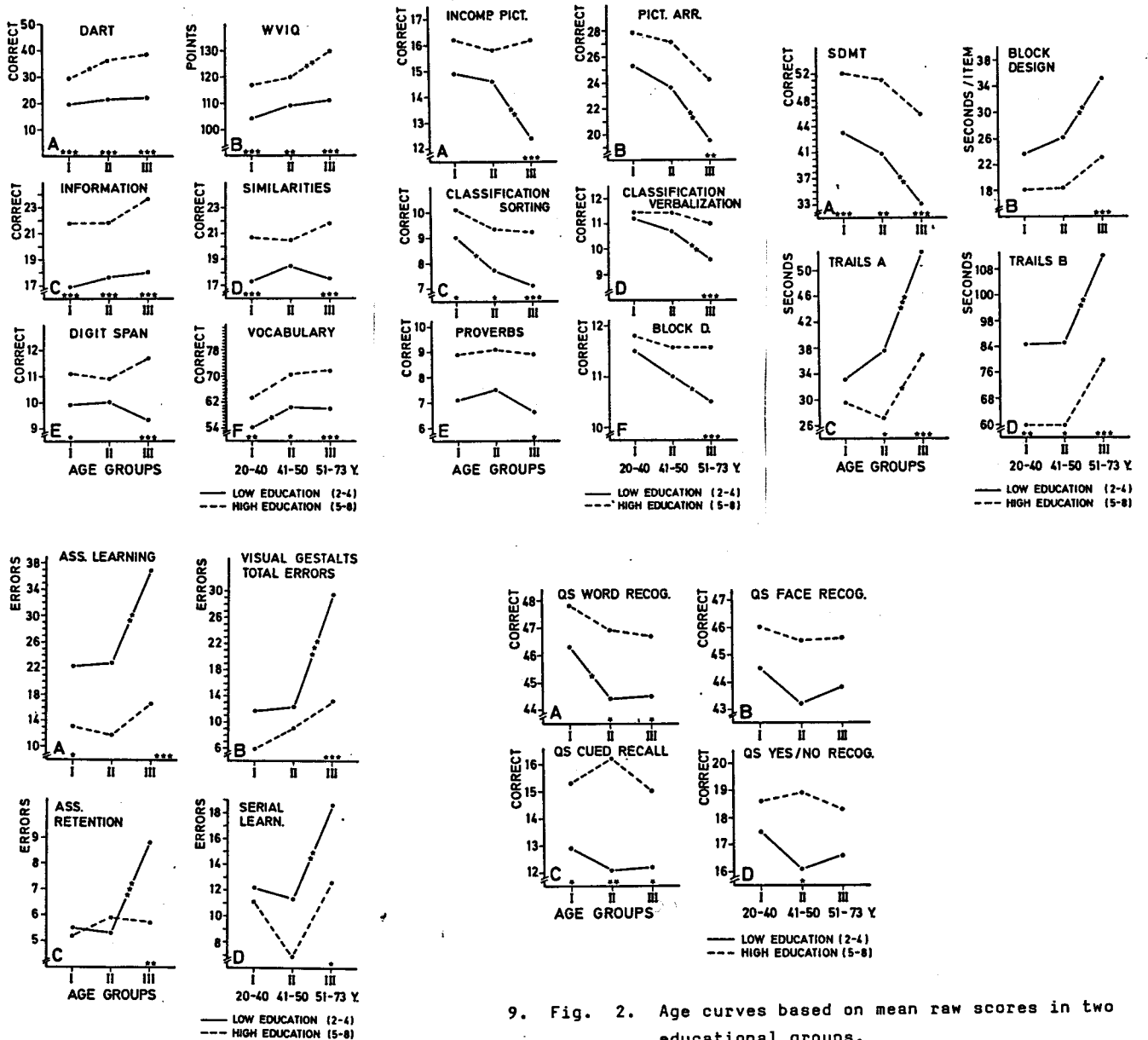
BB subtests	Factors			
	1	2	3	4
Proverb Interpretation				.82
Classification Test (Sorting)				.70
Associate Learning			.82	
Associate Retention			.87	
Visual Gestals Learning	-.75			
Visual Gestalts Cued Retention	-.68			
Digit Span Forwards		.86		
Digit Span Backwards		.77		
Sentence Repetition		.68		
Block Design (sec./item)	-.71			
Trail Making A	-.80			
Trail Making B	-.82			
SDMT		.67		

Label	Visuo-spatial	Memory Span	Verbal Memory	Abstraction
-------	---------------	-------------	---------------	-------------

8. Data analysis steps

1. Analysis of data for the construction of age and education curves based on raw data (fig2)
2. Testing of significance of differences between group means in analysis of variance (stars in fig. 2).
Comparison of data with other normal samples to determine representativeness.
3. Principal component analysis of data from 13 BB measures, followed by varimax rotation (table 2).
4. Conversion of raw scores to I-scores (\bar{x} 50; SD 10).
5. Computation of composite factor scores for the total BB and each of four factors by averaging the I-scores for the relevant subtests.
6. Exploratory regression analyses of background variables to identify significant contribution to variance.
7. Application of equations from the best regression model to individual subjects to compute expected scores.
8. Calculations of differences (residuals) between expected scores and observed scores in individual subjects.
9. Comparisons of difference-scores and clinical ratings of "dementia degree" in groups and individuals (neurological patients).
10. Comparisons of discriminations (rates of correct classification) based on uncorrected and corrected scores (in both single tests and composite measures) between normals and "brain damage" patients.
11. Several further steps to determine the validity in our approach in different clinical situations are in progress.

results



9. Fig. 2. Age curves based on mean raw scores in two educational groups.

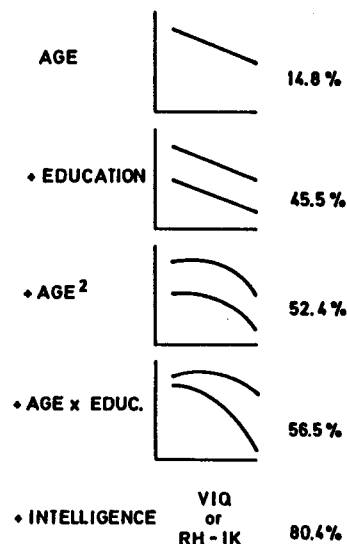
Significant differences between two age groups with similar educational background are indicated with asterisks in the curves. Significant differences between educational groups at the same age level are indicated with asterisks on the abscissa. One, two and three asterisks indicate differences at the .05, .01 and .001 levels of confidence, respectively. Note the indications of interactions between age and education.

10. Exploratory regression analyses.

For the mean total BB performance, 80.4% of the variance could be explained in the best regression model, illustrated schematically in fig. 3, which also indicates the stepwise increase in explained variance. This model includes a measure of verbal IQ, which in normals greatly increases the predictive power of the model. Other variables examined, including sex, contributed negligibly.

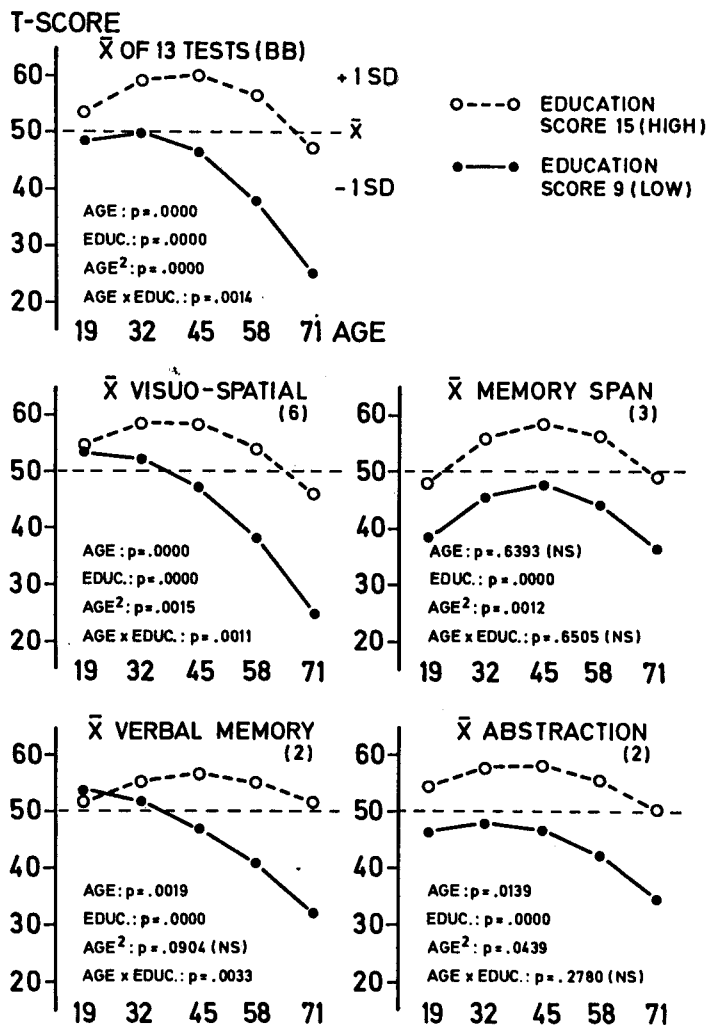
Expected mean scores over age and two (arbitrary) educational groups in the 5 BB summary measures are shown in fig. 4. The amount of explained variance is smaller in factors than in mean total, and smaller in single tests than in factors (we use composite measures to increase reliability). The interaction between age and education is significant for the visuo-spatial and verbal memory factors, and for the total mean.

\bar{X} BB VARIANCE EXPLAINED



11. Fig. 3. Schematic illustration.

EXPECTED MEAN SCORES



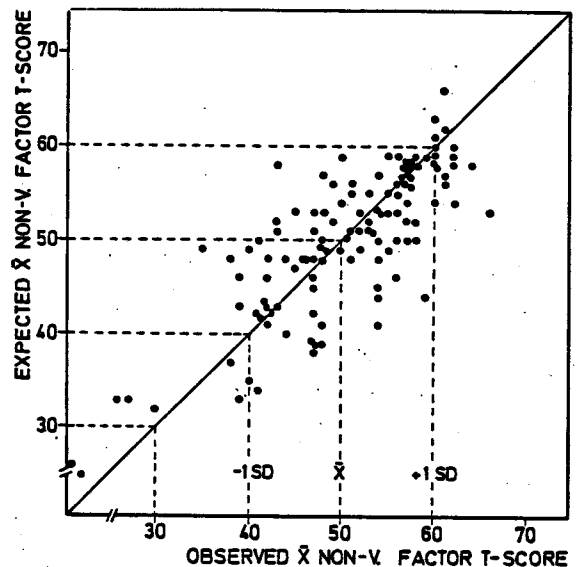
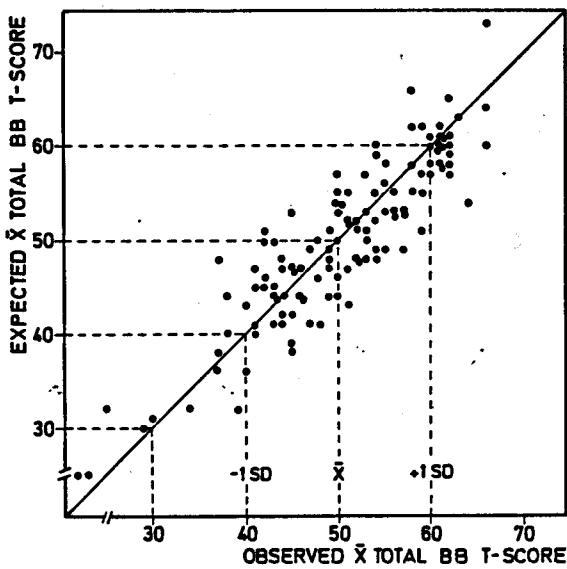
12. Fig. 4. Regression model without VIQ.

applications

13. Difference scores.

We have applied the regression equations derived from the analysis of scores from the normal subjects to compute expected scores. The expected mean total BB and factor scores have been calculated both with and without VIQ included in the equations. The differences between expected scores and observed scores may be used as an index of impairment. Illustrated are the relationships between expected and observed scores in \bar{x} total BB (fig. 5) and the impairment sensitive visuo-spatial factor score (fig. 6) in the 120 normal subjects.

14. Fig. 5. Expected and observed scores: mean total BB.



15. Fig. 6. Expected and observed scores: visuo-spatial factor.

As to be expected in a group of normal subjects, a normal distribution about zero difference is seen, with no deviant cases. (Not quite true, however. The two cases with the lowest observed and expected scores do have large negative difference scores. Both are old and have very low IQs, and we do not know whether they are indeed impaired. Our model may not be valid for individuals who are extreme (negatively) in both age and IQ).

16. Inclusion of VIQ in equations?

The inclusion of VIQ in the regression equation results in a rather small standard error of the mean difference score (SE 4.6-4.8 (T-scores with VIQ; SE 6.8-7.2 without VIQ) for total BB performance. This in turn means that smaller deviations of the observed score from the expected score become statistically significant compared to calculations based only on age and education. In a preliminary comparison of normals and patients with cerebral atrophy, a slightly improved discrimination (total misclassified: 18%) was observed when the VIQ was included. The problem with intelligence measures is, of course, that they may not be independent of brain damage. It is quite obvious that to some extent different subjects will be misclassified by equations with and without VIQ. In severe brain damage, VIQ should probably not be used as it may be both unnecessary and misleading, while our own preliminary data indicate that VIQ may validly and advantageously be used in mild brain damage. Much research is needed to delineate the proper use of VIQ in this context.

17. Statistical significance and impairment rating.

Computation of an "impairment degree" in the mean total BB performance and each of the four factors (or any other combination of tests as well as in single tests) is possible (and can be made routinely) based on the difference scores and their standard errors. The statistical likelihood of any such degree of impairment in a group of normal subjects can be calculated. We have tentatively designated 2/3-4/3 SE suspect; 4/3-6/3 SE mild impairment; 6/3-8/3 mild to moderate impairment, etc. In this computation, "suspect" carries p values of ab. .07-.25, and in "significant" impairment $p < ab. .08$ (one-tailed). We have compared these arbitrary impairment ratings to clinical ratings of impairment in patient populations, and found them meaningful. For both research and clinical purposes, profile analysis based on difference scores in factor clusters of tests seems promising to us. Among the unsolved problems with this approach are the limitations imposed on the range of possible T-scores in some factor scores due to ceiling or cellar effects in some tests. (This problem was not foreseen 5 years ago in the test construction/test selection phase of our project!).

18. Representativeness and limitations

A basic presumption for the validity of our regression equations in clinical applications is that our normal data are representative of the population at large. A comparison of our data with those of two studies on non-medical subjects suggests that this is the case. Spotwise comparisons with other studies have also been encouraging. For instance, the percentile distribution of our subjects on the Warrington Recognition Memory Test is almost identical to that of Londoners examined at Queen Square.

Any use of an approach as exact as this one must respect that validity presupposes that both subject characteristics and testing conditions are similar to those in the original study. In studies of Danish populations, both slight changes in instructions and other sources of tester influence could decrease the validity. Also the relationship between background variables and test performance may change over time, and we must investigate the continued validity in our own setting at intervals in the future.

Our model has been developed in a small country with a rather homogeneous population. It may be expected that a similar model in other cultures must be more complex, and must include other variables (e.g. sex, ethnic background, geographical locale, or other sub-cultural characteristics). While in more heterogeneous populations model development will be more difficult and will require a larger normal sample as its basis, the expected greater diversity of cognitive performance ability in heterogeneous populations may serve as the very argument for the necessity of the task.

19. Case illustration.

Sequelae after cardiac arrest.

42 year old female.

School: 10 years.

Occupational training: none (1).

Work: unqualified in supermarket.

Cardiac arrest 1/2 year before exam.

Duration uncertain, at least 5 min.

Coma 36 hours.

Hospital discharge to home after 2 weeks.

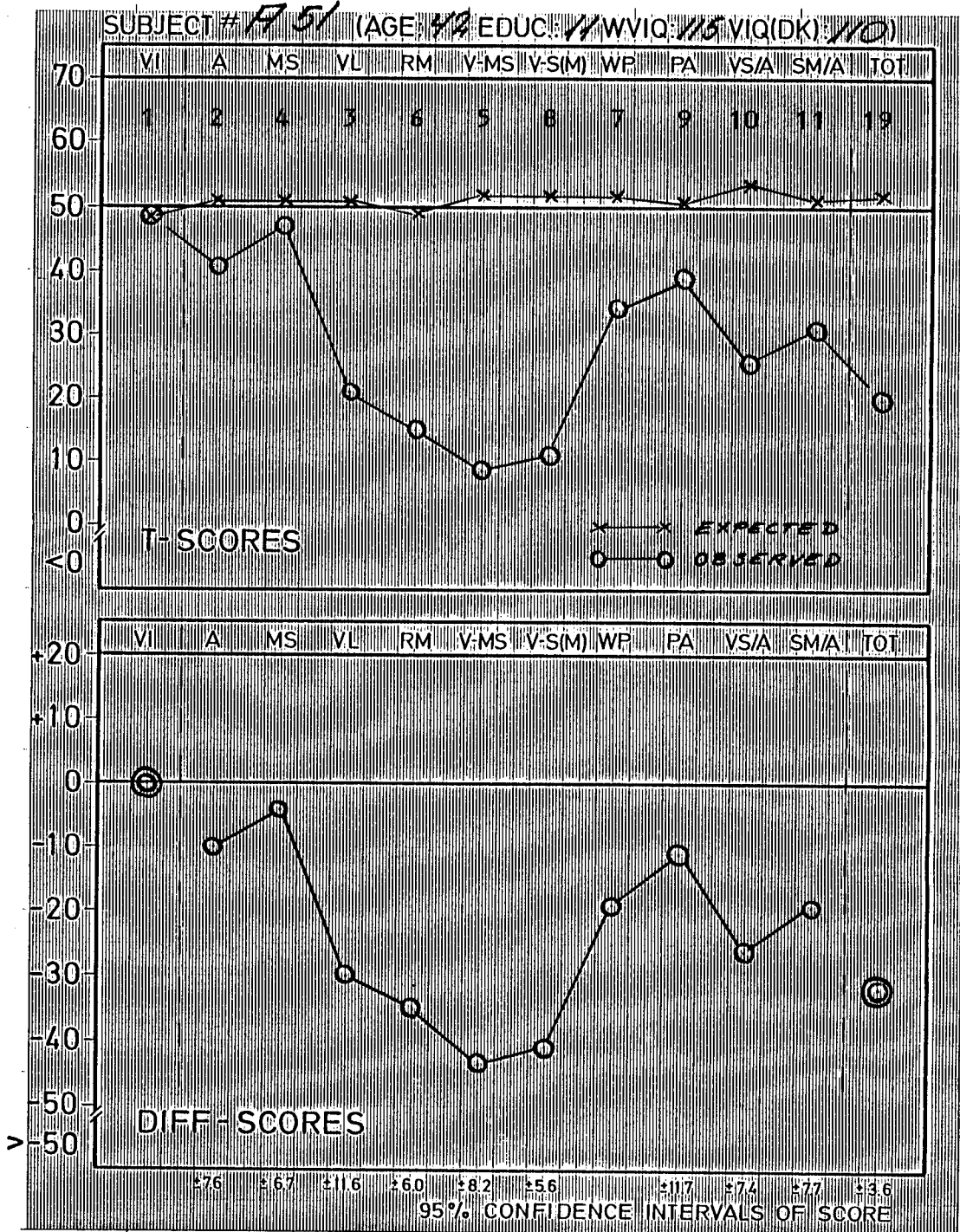
Maintains duties as housewife with difficulties.

Impression: Memory difficulties of amnesic character. Spatial and constructional deficits. Moderate dementia. Occupational therapy indicated to improve functions as housewife.

case example

SUBJECT NUMBER 51 IN GROUP 4
AGE 42 EDUCATION 11 IMP DEGREE 20

VARIABLE	OBS	EXP	DIF	DEK
1 VERBAL INTELLIGENCE	49	49	0	0
2 ABSTRACTION	41	51	-10	5
4 MEMORY SPAN	47	51	-4	0
3 VERBAL LEARNING	21	51	-30	25
6 RECOGNITION MEMORY	15	49	-35	30
5 VISUO-MOTOR SPEED	8	52	-43	30
8 VISUO-SPATIAL	11	52	-41	30
7 WAIS PERFORMANCE	34	52	-18	15
9 PASAT	39	51	-11	5
10 VISUAL SYNTHESIS/ANALYSIS	26	53	-27	20
11 SPATIAL MEMORY/ANALYSIS	32	51	-19	15
12 ABSTRACTION/WCSI	36	51	-15	10
19 TOTAL FACTOR 2-9	20	52	-32	30



conclusions

1. The normal individual variability in cognitive tests is great. This fact poses a problem for neuropsychological measurements of impairment.
2. In a homogeneous population like the Danish, the background variables of age, education, and intelligence account for most of the variance in composite measures.
3. We have developed a model based on regression analysis for expressing impairment in terms of differences between predicted and observed levels of performance. Preliminary analyses of the validity of this approach have been encouraging, but many more analyses are necessary to determine the potentials and limitations of the model. The precise model is limited to our language and culture.
4. Application of knowledge of the predictive power of background variables is essential for sensitivity and precision in the neuropsychological assessment of impairment.

Acknowledgements. We gratefully acknowledge financial support from the Danish Medical Research Council, and drawing assistance by Hanne Christiansen. Valuable discussions with colleagues, notably Peter Bruhn, have helped to clarify our ideas on the development of the model and its research and clinical uses.
Lisbeth Nymann typed.

Reference: Gade, A. & Mortensen, E.L. The influence of age, education, and intelligence on neuropsychological test performance. *Psykologisk Skriftserie*, Århus, 1985 (In press). Available in preprint from the authors at this conference upon request.