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ABSTRACT

The development of psychological methods for assessing the abilities of deaf students could aid in the formation of educational programs and the provision of vocational guidance. A battery of tests designed to measure a wide range of functions was administered to all eighth grade students, average age 15, in schools for the deaf in Sweden. All tests, with the exception of those intended to measure verbal ability, were nonverbal. Results from the factor analyses showed that whether the tests were speeded or non-speeded influenced the factor structure. Separate analyses of the boys' and girls' results revealed considerable differences in factor patterns, thus suggesting essential differences in the ability structures. For the girls there seemed to be a strong bond between verbal, numerical, and reasoning tests, and for the boys a corresponding bond between spatial, numerical, and reasoning tests. Comparisons of the results for these deaf groups and those typical of normal subjects are noted. It is suggested that if teaching in schools for the deaf were supplemented with more concrete, manipulative materials and visual aids, problem-solving and mathematical ability in deaf students could be more highly developed. Detailed descriptions of the tests employed and analyses of the resulting data are provided. (PR)

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THE STRUCTURE OF ABILITIES IN A GROUP OF DEAF ADOLESCENTS

Abstract. - The purpose of the research reported here was to develop psychological methods for the assessment of the abilities of deaf subjects as an aid to vocational guidance. All pupils in grade 8 (average age 15 years) in the schools for the deaf in Sweden were given a battery of tests, designed to measure a wide range of functions. All tests, with the exception of those intended to measure verbal ability, were non-verbal. The tests were given through non-verbal instructions and adapted for group administration. Mean differences were calculated for the results between deaf and hearing groups and for the results within the deaf group between sexes and classes (ability levels). Factor analyses were carried out on results from the girls' and boys' groups separately and for the total group on data from the same tests administered with and without speed limits.

Compared to hearing groups the performance of the deaf was - as expected - low in all tests involving knowledge (verbal, numerical, mathematical). In reasoning tests the results were somewhat lower than in hearing groups. In spatial, mechanical and dexterity tests, however, the results were about equal. Within the deaf group, A classes (high ability to follow the teaching) were superior to B and C classes (lower ability to follow the teaching) in all tests involving knowledge and in tests requiring speed. Girls were superior to boys in all verbal tests. The results from the factor analyses showed that speed is a variable that seems to have considerable influence on the factor structure. Analyses of results from tests given without a speed limit gave a more differentiated factor structure than when the tests were timed. The factor structure from the separate analyses on the boys' and girls' results showed considerable differences. For the girls there seemed to be a strong bond between verbal, numerical and reasoning tests. For the boys, on the other hand, spatial, numerical and reasoning tests showed a corresponding bond.

INTRODUCTION

The research presented in this paper deals with the ability structure in a group of deaf adolescents. The group consisted of prelingually deaf subjects, whose hearing had been seriously impaired at such an early age, that there had been no development of speech and language with auditory stimulus. This language deficiency is by definition the characteristic of those called "deaf" in this study.

The question of the immediate importance of language in thought processes and concept formation has largely come to dominate the psychological discussion of the problem of the deaf. The direct effect of a language deficiency can, however, hardly be isolated from the indirect effect, so long as we live in a verbal civilisation, where language is the most important medium for acquiring knowledge and information. In a verbal culture, a linguistic handicap results in a limitation of the flow of information, which should have a retarding effect.

During the years at school, there is in addition an educational handicap, since pure linguistic training takes such a disproportionate amount of time, that the time available for the acquisition of knowledge becomes limited. Moreover, the oral method of teaching seems to involve a largely imitative — receptive method of learning, which may not promote analytic or constructive thinking.

The deaf in our society should be considered a culturally deprived group. Studies made of groups whith normal hearing have shown that cultural deprivation has a retarding effect on the qualities which we use as a measure of intellectual capacity - the ability to imbibe theoretical knowledge (school results), the results of conventional intelligence tests.

Loss of the sense of hearing at an early age also has other consequences. In most cases, the child is the only deaf person in a hearing and speaking environment and this predicament must in itself involve a strong risk for a social trauma, which can have an inhibiting effect on the development of the personality. A deaf person's behavior is also modified in a more direct way. The loss of one of the senses robs the individual of part of the information about the world around him. His experiences have a different basis to those of a hearing person, as a result of which his imagination and ways of thinking probably have a different content and form.

Thus psychological assessment of the deaf involves working with subjects who differ from those with normal hearing in many respects and every attempt to measure their mental functions implies an intricate task.

PROBLEM

The purpose of the study was to work out methods of testing the aptitude of the deaf, i. e. to construct instruments for prognosis. The problem of validity is therefore central.

The first step should be to study construct validity - investigate the relation between the tests and try to chart the structure of ability in the deaf group. This is the stage which the investigation has reached at the present moment. The only way, however, to assess the prognostic value of a certain constellation of results in a subject, will be to follow him after he leaves school. This kind of follow up is planned for the future.

The study of the deaf means tackling a group, in which the structure of ability is unknown. It is necessary to be able to relate to some data. Therefore tests developed for hearing subjects have to be used and functions which are reasonably well defined in normal groups must be taken as the starting point. It is also possible that any discrepancies found between the test results of the deaf group and normal groups can provide hints on differences in thought processes. However, descriptions of disparities and agreements in results between deaf and hearing groups may not give the full picture. Quite apart from conceivable differences in the cognitive processes, the deaf group's educational handicap should be taken into account. This means that a comparison with normal groups in many contexts cannot give relevant information. A test, which at a certain stage measures reasoning ability may after a period of education and training measure no more than an automatic skill.

In this context, a validation of the test results with school results was considered of no value. The construction of test-batteries which produce results similar to those obtained in normal school work makes the testing a rather superfluous duplication. The most interesting subjects are those, whose school results do not tally with the success achieved later in working life.

METHODS AND PROCEDURE

On account of the deaf group's linguistic handicap, the testing had to centre around a core of non-verbal tests. In assembling the test-battery, efforts were made to select tests which would make it possible to measure a wide range of functions - inductive reasoning, spatial ability, perception, mechanical aptitude, dexterity, verbal, numerical and mathematical ability. It was considered necessary to include tests of knowledge. The level of knowledge must be determined if recommendations are to be made for future occupation and training. Moreover recording of discrepancies between the levels of ability and knowledge should be of diagnostic value. It is also important to include tests, which give information on other qualities than ability or skill. Quite different qualities might be decisive for successful adjustment to working-life. For this reason, Bender, Draw a Man and a Labyrinth test were included in the battery. The instructions for all the non-verbal tests were adapted, so that adequate instructions could be given solely by demonstration of the material, making no demands on linguistic comprehension. Practice examples were constructed to replace verbal instructions. The instruction material was transferred to slides, where suitable, in order to make group-instruction possible.

The first examination was carried out in the spring term 1965, when the pupils in grade 8 (average age 15 years) of all the Swedish schools for the deaf - located in the towns of Lund, Vänersborg, Stockholm and Härnösand - were tested. In Stockholm two pupils were absent, but at the other schools all pupils took part. The second examination took place during the spring term 1967. In Sweden the schools for the deaf admit pupils only every other year, so there was no grade 8 in 1966. The pupils of all the schools were tested in the 1967 study, but the Stockholm school had to be excluded from the data, partly because a group of pupils with good residual hearing had been placed among the deaf pupils and partly because the results from this school could not be considered reliable for various other reasons. The group tested in 1965 totalled 68, 25 girls and 43 boys. The 1967 group totalled 56, 23 girls and 33 boys.

The testing was performed in groups. In 1965 two days were required and in 1967 two and a half days. The pupils worked in their classes, and the testing was arranged to fit the school timetable, with pauses during the usual breaks. The size of the classes varied from between three and nine pupils. During the manual tests, the classes were divided when necessary, so that close observation of behaviour could be made.

The first study was arranged as a methodological pilot study, which aimed at obtaining as much data as possible, as a means of finding out which methods of testing were most suitable for future use. When tests which in the 1965 study proved unsuitable were removed, there remained 22 tests. The results of these were treated statistically. On the basis of these results, a number of other tests were added to the test-battery for the 1967 study in order to augment a factor, illuminate a function or reveal a new dimension of behaviour.

In the 1965 study the tests were administered with the same time-limits as in normal groups. In order to elucidate the effect of the time-limits on the results, a number of tests in the 1967 study were administered with a change of pen (pencil, red ballpoint, blue ballpoint) at given times. All pupils were then given the chance to continue working until they had finished or gave up because they could not solve any more problems.

DESCRIPTION OF THE TESTS

The tests used only in 1967 are marked x)

The tests used only in the 1965 study are marked xx)

Raven's Progressive Matrices

Group version. This test is presumably so well-known that no further description of it is necessary. Instruction by individual demonstration of the first item and checking that the next two were solved correctly. 60 items. No time limit. Progressive degree of difficulty in separate series.

Matrices II x)

Another version of Raven's Matrices, where the answer figure is absent. Instead the missing figure is to be drawn in the matrix given. The point of the new version was partly to try to find out what effect the absence of alternative answers could have on the test results, partly to try to check methods of solution. After the elimination of the items which were not suitable for this version, through being too difficult to draw (or to mark), 53 items remained. No time limit. Progressive degree of difficulty in separate series.

D 48

French version of an English test, constructed to obtain a non-verbal intelligence test, analogous with Raven's Matrices. The test contains exclusively identical figures, dominoes. The problem in each task is to discover the system according to which the dominoes are arranged and fill in the correct number of spots on the final blank domino. Answer sheets were not used in the deaf group, instead the answer was written directly on the test paper. 4 examples. Instruction by demonstration with slides, on the blackboard and individual help with examples. Time 25 minutes. 44 items. (All finished after 25 minutes.) Unevenly progressive degree of difficulty.

Reading Comprehension xx)

(Aimed at grade 4.) Reading passages of text and answering two questions on the content by marking one of five alternatives per question. One example. Instruction by individual help with the example. Time 30 minutes. 26 passages. The test was too difficult. The pupils' behaviour during the test showed clearly that a majority of them marked at random. The test was eliminated as unsuitable for the deaf group, despite the fact that the results gave an approximately normal distribution.

Vocabulary xx)

(Aimed at grade 4.) Marking one of five alternative answers. The test consists of finding the right word to complete a statement. 2 examples. Instruction by individual help with the examples. Time 12 minutes. The test was too difficult. It did not differentiate and was eliminated from the statistical treatment.

Reference Book

(Aimed at grade 4.) Marking one of four alternatives as the answer to a question. The right answer to the question can be found in a diminutive reference book, arranged in alphabetical order, which each subject is given. 3 examples. Instruction by individual help with the examples. Time 15 minutes. 24 items. (All finished after 25 minutes.)

Reading Speed

(Aimed at grade 4.) Reading of text and underlining one of three alternative words which occur within parenthesis at regular intervals in the text. Practice passage with three words to underline. Instruction by individual help with the practice passage, Time 5 minutes. 33 items. (All finished after 20 minutes.) The narrow time limit for the test was considered unsuitable. The measurement of reading speed is of relatively little interest in a linguistically handicapped group. On the other hand, it was decided that the test could serve as a good reading comprehension test with a more generous time limit.

Reading Speed DLS x)

(Aimed at grade 4.) Reading of text and underlining one of three alternative words, which occur within parenthesis at regular intervals in the text. Time 4 minutes. 26 items. (All finished after 9 minutes.) As with the other reading speed test this test was considered a good reading comprehension test when given a generous time limit.

Sentences xx)

(Aimed at grade 4.) Sentence completion test with one or two blanks in each sentence. 3 examples. Demonstration with slides and individual help with the examples. Time 6 minutes. 20 items. The test was too difficult and did not differentiate. It was eliminated from the statistical treatment.

Opposites

(Aimed at grade 2.) The test involves giving the opposite to a given word. Marking one of five alternatives. 3 examples. Demonstration with slides and individual help with the examples. Time 5 minutes. 25 items. (All finished after 7,5 minutes.)

Writing a Letter

The task set is the writing of a letter (free choice of recipient), which is assessed according to the following principles.

1. Ability to pass on information. A letter consisting solely of standard phrases got a low assessment, even if it was grammatically correct.
2. Complexity and flexibility in sentence-formation and choice of words. Use of subordinate clauses, for example, raised the assessment appreciably, compared to a letter which consisted solely of short, simple sentences.
3. Ability to express oneself grammatically.
4. The length of the letter could influence the assessment in extreme cases.

Addition

The calculation of simple additions. Instruction by individual help in solving examples. Two parallel test-halves, each with 10 examples and 48 items. Time for each 4 minutes.

Multiplication

The calculation of simple multiplications. Instruction by individual help in solving the examples. Two parallel test-halves, each with 10 examples and 48 items. Time for each 4 minutes.

Arithmetic

Problems to calculate with one of the four rules of arithmetic. 4 examples. Instruction by individual help in solving the examples. Time 5 minutes. (In the 1967 study an additional five minutes was given.) Progressive degree of difficulty.

Combination of Numbers x)

(The test is taken from a trial version, intended for grade 4.) With a number of given figures, an equation is to be set out, one part of which contains only one number. 3 examples. Demonstration on the blackboard and individual help with the examples. Time 7 minutes. 18 tasks. (All finished after 20 minutes.) Progressive degree of difficulty.

R 16 C

The test consists of problems to be calculated with one of the four rules of arithmetic. In each problem one or more figures has been left out and replaced by a dot. The subject has to find out which figures should stand in place of the dots. Five examples were given as instruction. Demonstration on the blackboard and individual help with the examples. Time 15 minutes. 24 items. (All finished after 20 minutes.) Progressive degree of difficulty.

Identical Forms

The test requires the identification of a given figure in a row of five alternatives. 5 examples. Demonstration with slides and individual help with examples. Time 5 minutes. 60 items.

Proof Reading x)

Proofs containing text. Demonstration with slides and individual help with examples. 8 examples. Time 6 minutes. 140 items.

Substitutes

In this test ten letters from the Canaanitic alphabet are to be coded from 0-9. A key to the code is printed at the top of each test sheet and can be used during the entire test. Demonstration of the first ten items on a wall-chart with the key and the first line of the test powerfully magnified. Time 5 minutes. 250 items.

Puzzle x)

A black rectangle, with one or two missing pieces, is to be completed. One or two of five alternatives to be marked. 3 examples. Demonstration with slides and individual help with examples. Time 6, 5 minutes. 20 items. (All finished after 11, 5 minutes.) Progressive degree of difficulty.

Copying

A given pattern is to be copied on to a dotted area, in such a way that the proportions and placing are in exact agreement with the pattern. 8 examples. Demonstration with slides and individual help with the examples. Time 6 minutes. 36 items. (All finished after 12 minutes.)

Surface Development

The subject is to imagine a given two-dimensional figure folded so that it corresponds to one of four alternative figures. Demonstration with slides and individual help with the examples. When necessary folding of paper to three-dimensional figures to illustrate the idea behind the test. 5 examples. Time 6 minutes. 40 items. (All finished after 13 minutes.)

NIIP

Test of memory for designs. The tasks involve memorizing a geometric figure, shown on a wall-chart for 10 seconds, and then drawing the figure as accurately as possible. No time-limit for the drawing. 8 items.

Cube Counting x)

Each task consists of a pile of cubes, some of which are hidden behind those in front. The number of cubes in the pile is to be stated, including those hidden. Instruction by demonstration with slides and with three-dimensional models. Individual help with the examples. 3 examples. Time 12 minutes. 40 items. (All finished after 14 minutes.)

Reels x)

Each task consists of a group of reels (circles), each of which is marked with an arrow. The idea is to mark with a pen how a string must be pulled to make the reels move in the direction shown by the arrows. Demonstration of the task by a mechanical model, where a weighted string is pulled over reels marked with arrows, so that the reels move is the same direction as the arrows. Afterwards two examples with individual help. Time 15 minutes. 14 items. (All finished after 15 minutes.)

MP x)

A test taken from a test-battery for testing mechanical-practical ability. (Given as an individual test.) The task is to match a pile of blocks with a picture of a pile of blocks, so that the two together form a cube. Task demonstrated with the picture of a pile of blocks also in the form of real wooden blocks, showing quite clearly that a cube can be formed. No time limit. 8 items.

F 1

The same type of test as Rupp's test. The test consists of a test sheet, in the upper left corner of which a pattern of T-shaped figures has been started. The task is to continue the pattern until the entire sheet is filled. Time 20 minutes. Assessment of the results according to a type-series, graded from 1 to 9. The results in the deaf group were low. They were so low that they could not be assessed on the nine-point scale, since that gave a large cluster of very low values. Instead, a rough division was made on a three-point scale in accordance with the following principles:

1. Complete absence of any conception of pattern;
2. Conception of pattern demonstrated by some part of the drawing showing correct reproduction;
3. Obvious conception of pattern, reasonable execution.

This means of assessment produced an approximately normal spread.

Bender

The test is intended to measure "general maturity" (Pascal & Suttell, 1951) or "general adjustment" (Farkell, 1966). It consists of nine simple figures, which are to be reproduced. The figures are presented one at a time. Each individual was given his own series of pictures, joined with a plastic spiral, and could work at his own pace. No time limit. Assessment according to Pascal & Suttell.

Labyrinths x)

In contrast to Portéus's Maze Test, this test is constructed as a group test. There is no time limit, but the subjects are instructed to raise a hand each time they complete one section of the test and the time is registered for each individual. The form of the test used here consists of six labyrinths, in which the path from start to finish is to be marked with a ballpoint pen. In assessing the results, each time the line has entered the entrance to a blind alley was noted as a mistake. The touching of the walls of the labyrinth with the drawn line was not counted as a mistake. Motor factors were not to influence the assessment. Points for time were not taken into account. Registration of time is probably necessary, however, in order to create a certain pressure and prevent the tasks being studied too long beforehand.

Draw a Man x)

Assessed according to Goodenough (1926).

Gothenburg Box

(Same type of test as Minnesota Mechanical Assembly.) The test consists of eight different objects which have been taken to pieces and are to be put together again - electric light socket, tap, micrometer screw, bicycle hub, doorbell, mouse-trap, saw set, door-lock. Instruction by natural gestures. Time 20 minutes.

Crawford Screw

The task involves screwing small screws as quickly as possible into threaded holes in a metal plate with the help of a screwdriver. Instruction by demonstration of the task. Time 5 minutes.

Crawford Pin

The task consists of placing small pins as quickly as possible in the holes of a metal plate with the help of a pair of tweezers. Instruction by demonstration of the task. Time 1, 5 minutes.

O'Connor

The task is to place three pins at a time with one hand in the holes in a wooden block as quickly as possible. Instruction by demonstration of the task. Time 8 minutes.

Wirebending

The test involves bending a piece of wire so that it is a copy of a model on a larger scale. Instruction by natural gestures. A piece of wire of a corresponding length and thickness to that in the model is shown together with a piece of wire of the kind that is to be bent, to demonstrate that the copy must be smaller. The model is on view throughout the test. No time limit. For assessment of the results there is a type-series, on a 1 to 9 scale.

DATA TREATMENT

The statistical treatment comprised:

A. The calculation of mean differences between sexes and classes[1)] within the deaf group and to a limited extent the calculation of mean differences between the deaf group and a normal group of the same age.[2)]

B. Factor analyses.

Analyses of the results of the 1965 study and the 1967 study with the same test battery and time limits.

Analyses of the results from the 1967 study with the same test battery, but with no time limits for several of the tests.

Analysis of the supplemented test battery from the 1967 study with no time limits for several of the tests.

Analyses of the combined study groups 1965 and 1967, divided into boys and girls. The same test battery and time limits as in the first two analyses.

The factor analyses were carried out with the method described by Jöreskog (1963) using an IBM 7090 with orthogonal rotation in accordance with Kaiser's varimax method, based on the concept of simple structure. The program was for all the analyses specified to include from three to ten factors. The transcription from the program gives criteria for the testing of the number of significant factors -

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1) The pupils at the schools for the deaf were divided into A, B and C classes according to their ability to follow the teaching. The calculation of mean differences could only be carried out for the A classes in relation to the rest. The division into three classes was not consistent.

2) For the majority of the tests used, norms for normal groups were available, in many cases for different age levels. For a few of the tests, material for comparison was collected from a group of grade 8 pupils with normal hearing.

U(k) criterion for testing the residual variance and T(k) criterion for testing the smallest number of latent roots to the transformed matrix. A rough estimation of the number of significant factors can also be obtained by using Kaiser's criterion according to which factors with latent roots greater than 1 are significant. In the present study, the criteria give the same number of factors - with the exception of the material on the girls.

For testing the significance of the factor loadings, the method developed by Harman and Holzinger (Harman, 1960) was used. The 1 per cent level was taken as the lowest point of significance.

RESULTS AND DISCUSSION

Levels of Achievement

Comparison made within the deaf group showed that the A classes achieved consistently better results in all tests involving knowledge and in tasks requiring speed. The girls were superior in linguistic tests, while the boys had better results in the practical-technical tasks.

In comparison with normal groups, the results of the deaf where on a low level in all tests involving knowledge. This was expected and tallies with results from other studies of deaf groups (Juurmaa, 1963, Wrightstone, Aronow & Moskowitz, 1962). In the inductive reasoning tests, Raven's Matrices showed about the same fall of standard as reported by Oléron (1949). Matrices II followed the same pattern while the results for D 48 were surprisingly low. In tests requiring speed and in practical-manual tests the results were equally good. This also applied to the spatial tests, with the exception of Cube Counting and F 1. For Labyrinths, Draw a Man and MP there was no comparative material from normal groups. The performance in Bender, on the other hand, showed close agreement with the results from a normal group of grade 8 pupils (Farkell, 1966).

Various explanations could be offered for the surprisingly low results in D 48 compared to Raven's Matrices. The common features of the two tests are that they do not directly involve knowledge and that they are free from alphabetical and number symbols. There are, however, essential differences in the way the tests are built up. One difference is that D 48 has no alternative answers. Matrices II, which also lacks alternative answers does, however, not give a higher correlation with D 48 than Raven's Matrices does. Another difference is that D 48 - in contrast to Raven's Matrices - is not constructed in clearly separated series. In D 48 the method of solution changes without any previous instruction. A third difference is that the tasks in D 48 give a rather unstructured perceptual impression. The test appears to need more analysis of detail and restructuring than Raven's Matrices. The decisive difference between the tests is probably that D 48 demands a greater ability to change the principle of solution and to analyze and restructure the test material.

The low results of F 1 may seem puzzling considering that the deaf group achieved results on the same level as normal hearing groups in most other spatial and reproduction-of-designs test. The critical function in F 1 seems to be the ability to isolate a figure from its background. The T-shaped figure has to be broken out of the pattern, so that a pattern of T-shaped figures can then be built up. This is the same mental operation as the one required in various forms of Gottschaldt-figures tests. Witkin et al. (1962) have used a Gottschaldt-figures test extensively in connection with their studies of the trait called "field-independence-dependence" which Witkin regards as a "cognitive style". In addition to the Gottschaldt-figures the tests of field-independence-dependence include the Rod-and-Frame test and the Body-Adjustment test. In the Rod-and-Frame test the subject sees a luminous rod inside a luminous frame in a dark room, both rod and frame being tilted; the subject has to adjust the rod until he thinks it is at the true vertical. In the Body-Adjustment test the subject is seated in a chair in a small room, both room and chair are tilted, and the subject has to adjust his chair to what he considers the true vertical.

Witkin (1964) relates field-independence-dependence to adaptive flexibility, which includes the ability to change the principle of solution and restructure material. Since this was considered crucial in solving the problems in D 48, adaptive flexibility might be a quality required for successful performance in this test.

Now a possible connection between the Body-Adjustment test and a subjects intellectual performance deserves further analysis. A person's judgment of the position of his own body is partly formed with the help of the vestibular apparatus in the inner ear. Prerequisite for a good result in the Body-Adjustment test, should be that the body's ability to register proprioceptive stimuli is intact. It is known, that among the deaf there is a proportion of inner ear injuries, which may have affected not only their hearing, but also their vestibular apparatus. One may well ask, whether there could be some hidden connection between vestibular defects and intellectual performance. This might be part of the explanation of the low scores of the deaf on both F 1 and D 48. The low scores in Cube Counting may have the same explanation. Cube Counting measures "spatial orientation", where according to Guilford (1967) the frame of reference is primarily the person's own body, in his three-dimensional field with himself at the origin. According to this definition an impaired ability to perceive the position of one's own body ought to affect tests which measure spatial orientation.

The questions outlined above are now being tested. During the spring term 1969, data have been collected from another group of deaf pupils in grade 8. Tests for measuring field-independence-dependence (the Rod-and-Frame test and several Gottschaldt-figures test) were then included. A medical investigation is now being carried out to elucidate the presence of any vestibular defects.

Factor Analyses

The factor analysis of the results from the 1965 study gave an undifferentiated pattern. A five factor solution produced:

I. A symbol factor, which was dominated by the numerical tests, but which also contained high loadings on all verbal tests.

II. A spatial-inductive factor, which contained all the spatial and inductive reasoning tests.

III. A practical-mechanical factor, which was dominated by the practical-mechanical and dexterity tests, but which also contained a spatial component.

IV. A motor factor, described as such, since it emerged as a stable factor in later analyses, although in this analysis it was possibly a random factor.

V. A verbal fluency factor, named thus because of loadings on verbal and speed tests.

A more differentiated factor structure was obtained for the group studied in 1967. A six factor solution (cf. Table 1) gave:

I. A symbol factor, which was dominated more pronouncedly by the numerical tests.

II. A spatial-inductive factor.

III. A motor factor, which had become stable.

IV. A practical-mechanical factor.

V. A perceptual speed factor.

VI. A verbal factor with significant loadings only on the verbal tests.

In the factor analysis from the same group based on results from tests with no set time limits[1], a well differentiated factor structure was obtained. A rather clearly defined numerical factor emerged and the verbal factor appeared earlier. A seven factor solution was chosen, even though the seventh factor could not be defined. It was included, however, since it anticipated a factor which emerged clearly in the analysis of the supplemented test battery and was there described as a planning factor. The seven factors are in the following order (Table 2):

I. Numerical.

II. Spatial-inductive.

III. Verbal.

IV. Practical-mechanical.

V. Motor.

VI. Perceptual speed.

VII. Undefined.

The factor analytic results showed that speed is a variable which can have a considerable influence on the factor structure in deaf groups. The effect that the speed element has in a test battery is probably rather complicated, however. On the one hand, speed can increase the covariation between the tests, since the speed component in the battery raises the correlations. On the other hand, the size of the correlations depends on the reliability of the tests. By prolonging a test, which is the result of removing the time limit, it may be possible to increase the reliability and thus obtain higher intercorrelations. By raising the reliability, one may also increase the validity, which should lead to relatively higher correlations between tests which measure the same ability and so produce a more differentiated factor structure.

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1) The numerical and dexterity tests were still timed. This also applied to Substitutes and Identical Forms.

Table 1. Factor structure (1967, with time limits, 22 tests)

N = 56

Unrotated factor loadings

	1	2	3	4	5	6
Reading Speed	.54	-.58	-.13	.17	.01	-.36
Reference Book	.73	-.37	.02	.03	-.15	.03
Opposites	.60	-.27	-.27	-.05	.00	-.25
Writing a Letter	.61	-.30	-.50	-.07	.26	-.07
Raven's Matrices	.60	.57	-.05	-.03	-.15	.03
R 16 C	.70	.27	.30	-.15	.14	-.10
D 48	.66	.35	-.13	.02	-.19	.07
Copying	.52	.34	-.41	-.05	-.19	.03
Surface Development	.33	.31	-.00	.26	-.30	-.28
Identical Forms	.55	-.21	.04	.17	-.53	-.01
Arithmetic	.80	-.10	.24	-.19	.14	.13
Addition	.87	-.16	.19	.15	.01	.08
Multiplication	.82	-.20	.27	-.09	.08	.15
Substitutes	.63	-.20	.25	-.10	-.18	.08
Crawford Pin	.39	.14	-.37	.31	.18	.27
O'Connor	.47	.08	-.37	.38	.12	.43
Wirebending	.54	.39	-.14	.16	-.00	-.26
Bender	.41	.06	-.23	-.13	-.06	.11
NIIP	.65	.40	-.07	-.22	.16	-.21
F 1	.51	.39	-.23	-.40	-.02	-.03
Gothenburg Box	.22	.46	.33	.49	.22	-.23
Crawford Screw	.23	.30	.16	.40	.21	.03
	7.61	2.31	1.39	1.13	.85	.78

Varimax-rotated factor loadings

	1	2	3	4	5	6	h^2
Reading Speed	.37	-.11	-.04	.01	-.22	-.77	.80
Reference Book	.65	.10	-.18	-.07	-.28	-.38	.69
Opposites	.31	.26	-.11	-.07	-.14	-.61	.57
Writing a Letter	.25	.28	-.40	-.15	.11	-.68	.79
Raven's Matrices	.22	.70	-.19	.28	-.22	.11	.71
R 16 C	.56	.50	.06	.37	.06	-.07	.71
D 48	.29	.59	-.27	.13	-.38	-.01	.67
Copying	.05	.63	-.34	-.01	-.25	-.13	.59
Surface Development	.00	.30	.01	.36	-.46	-.09	.44
Identical Forms	.45	.07	-.10	-.05	-.64	-.18	.66
Arithmetic	.80	.31	-.11	.09	.08	-.17	.79
Addition	.76	.18	-.25	.24	-.20	-.27	.85
Multiplication	.84	.20	-.14	.10	-.02	-.19	.81
Substitutes	.69	.15	-.00	-.03	-.22	-.11	.56
Crawford Pin	.06	.19	-.65	.17	-.01	-.13	.51
O'Connor	.17	.13	-.79	.13	-.09	-.09	.71
Wirebending	.08	.51	-.14	.41	-.20	-.23	.55
Bender	.19	.36	-.24	-.12	-.08	-.12	.26
NIIP	.26	.72	-.03	.27	.07	-.21	.71
F 1	.17	.77	-.08	-.06	.04	-.06	.63
Gothenburg Box	.03	.09	-.02	.83	-.05	.05	.70
Crawford Screw	.09	.04	-.22	.55	.00	.06	.37
	3.94	3.48	1.72	1.76	1.20	1.95	

Loadings underlined are significant at the 1 per cent level.

Table 2. Factor structure (1967, no time limits, 22 tests)

N = 56

Unrotated factor loadings

	1	2	3	4	5	6	7
Reading Speed	.66	-.29	.36	.10	.27	.19	-.14
Reference Book	.57	-.34	.18	-.17	.10	.23	.02
Opposites	.60	-.17	.43	.01	.20	.19	-.11
Writing a Letter	.55	-.31	.57	.12	.03	.16	.15
Raven's Matrices	.67	.50	-.07	-.05	-.14	-.08	-.08
R 16 C	.69	.17	-.26	-.05	.10	-.06	.32
D 48	.67	.32	.05	.01	-.34	.03	-.16
Copying	.55	.42	.31	-.04	-.14	-.00	-.04
Surface Development	.57	.68	-.00	-.09	.07	.13	-.15
Identical Forms	.49	-.22	-.06	.12	-.40	.49	.07
Arithmetic	.88	-.25	-.18	-.12	.02	-.14	-.06
Addition	.83	-.24	-.19	.20	-.05	.05	-.01
Multiplication	.82	-.35	-.23	-.05	.06	-.08	-.09
Substitutes	.61	-.33	-.22	-.10	-.12	.22	.19
Crawford Pin	.37	.08	.24	.44	-.23	-.25	.04
O'Connor	.46	-.03	.20	.46	-.26	-.27	-.09
Wirebending	.56	.39	.14	.19	.09	.21	.17
Bender	.40	-.00	.16	-.05	-.22	-.13	.16
NIIP	.72	.35	.09	-.18	.23	-.11	.05
F 1	.56	.32	.24	-.29	-.10	-.07	.32
Gothenburg Box	.23	.42	-.34	.50	.30	.09	.17
Crawford Screw	.24	.25	-.22	.41	.14	-.16	-.08
	7.94	2.36	1.39	1.14	.82	.73	.46

Varimax-rotated factor loadings

	1	2	3	4	5	6	7	h^2
Reading Speed	.32	.15	.79	.05	-.16	.10	-.05	.79
Reference Book	.43	.12	.54	-.15	.02	.20	.09	.56
Opposites	.22	.25	.72	-.03	-.14	.09	-.00	.66
Writing a Letter	.21	.08	.63	-.15	-.50	-.03	.29	.80
Raven's Matrices	.28	.77	-.03	.18	-.20	.05	-.03	.74
R 16 C	.54	.43	.04	.31	-.03	.05	.33	.69
D 48	.26	.66	.05	.02	-.33	.26	-.11	.70
Copying	.02	.69	.21	-.00	-.26	.07	.06	.59
Surface Development	.07	.86	.09	.28	.04	.04	-.09	.84
Identical Forms	.33	.10	.17	-.03	-.14	.73	.00	.70
Arithmetic	.84	.29	.27	.03	-.19	.02	.01	.90
Addition	.70	.18	.29	.24	-.29	.28	-.01	.82
Multiplication	.85	.15	.30	.08	-.15	.07	-.04	.87
Substitutes	.64	.08	.18	-.00	.00	.39	.17	.63
Crawford Pin	.03	.17	.11	.16	-.66	.05	.07	.51
O'Connor	.16	.14	.15	.13	-.72	.07	-.06	.61
Wirebending	.04	.53	.29	.37	-.13	.21	.19	.61
Bender	.22	.26	.09	-.14	-.29	.08	.22	.28
NIIP	.33	.68	.29	.17	-.04	-.18	.16	.74
F 1	.18	.64	.14	-.11	-.12	.02	.44	.67
Gothenburg Box	.02	.18	-.06	.82	-.02	.05	.06	.72
Crawford Screw	.10	.14	-.06	.53	-.23	-.09	-.12	.39
	3.48	4.00	2.44	1.52	1.81	1.00	.59	

Loadings underlined are significant at the 1 per cent level.

One apparently simple explanation of the undifferentiated Factor structure for the group studied in 1965 was the circumstance that all the tests were then administered with a break at the time limits and that the actual test situation for this group could have been influenced by the pressure of time to an extent that was not the case in 1967, when the pupils were largely allowed to work until they had finished the tests. There were, however, other differences in the groups which could not be attributed to the way in which the tests were administered. The extent to which the more speed-influenced test situation for the 1965 group might have caused the undifferentiated factor structure for this group, is a question which cannot be answered.

The supplemented test battery for the 1967 group gave with a six-factor solution (Table 3):

I. Numerical factor
II. Spatial-inductive factor
III. Verbal factor
IV. Practical-mechanical factor
V. Planning factor
VI. Spatial-orientation factor.

No motor factor and no perceptual speed factor were obtained in this analysis, because the dexterity and speeded routine tests had been excluded.

In the analysis of this supplemented test battery it proved possible to augment the practical-mechanical factor with the newly added test, Reels. By significant loadings from R 16 C and Reels, the factor was given a more theoretical trend. The methods of solution in Reels and R 16 C are not practical-manual. Since it had not been possible to find theoretical-technical tests suitable for use in deaf groups, this combination of tests, which gives the factor a rather more theoretical-technical slant, is particularly satisfactory. The newly added test, Labyrinths, dominates a factor, which was called a planning factor. O' tests found in the factor are F 1, which had a significant loading, Reels and R 16 C, which were on the borderline to significance. The common feature of these tests is that it is necessary in all four to think ahead in order to solve the problems. Mention has been made earlier of the importance in assessment to include measurements of other aspects of the personality than abilities and skills. Quite different qualities may be decisive for successful adjustment to working life, e. g. the ability to plan and anticipate the effect of one's actions. Admittedly, Labyrinths measures only a very concrete and limited form of forethought, but what is being sought here is an attitude,

Table 3. Factor structure (1967, no time limits, 28 tests)

Unrotated factor loadings	1	2	3	4	5	6
Writing a Letter	.54	.39	.46	-.00	-.25	-.12
Raven's Matrices	.72	-.46	.01	-.08	-.03	.30
D 48	.70	-.28	.02	-.13	.06	.13
Addition	.77	.30	-.27	.11	.01	.10
Multiplication	.78	.41	-.30	-.05	.07	.03
Substitutes	.55	.32	-.24	-.04	-.13	.12
Wirebending	.56	-.31	.08	.30	-.01	-.09
Bender	.43	-.01	.12	-.21	-.22	.07
NIIP	.75	-.28	.03	.07	.02	-.21
F 1	.60	-.30	.16	-.21	-.25	-.15
Gothenburg Box	.21	-.34	-.32	.58	-.14	.11
Puzzles	.63	-.56	.12	-.16	.14	-.02
DLS	.69	.41	.29	.09	.18	.00
Matrices II	.78	-.36	.17	-.01	-.17	.20
Combination of Numbers	.44	.00	-.21	.17	-.11	-.05
Proof Reading	.61	.53	.09	-.07	-.02	.00
Reels	.45	-.42	-.12	.26	-.33	-.20
MP	.29	-.34	-.18	.05	.22	-.16
Cube Counting	.34	-.25	-.34	-.12	.30	-.47
Labyrinths	.48	-.22	-.16	-.15	-.27	-.27
Opposites	.62	.27	.40	.12	.09	-.07
R 16 C	.69	-.15	-.36	.09	-.23	-.18
Copying	.58	-.39	.25	-.11	.13	-.14
Surface Development	.62	-.60	.03	.15	.28	.02
Arithmetic	.85	.28	-.24	-.15	.04	.03
Draw a Man	.60	-.15	.37	-.23	-.09	-.06
Reading Speed	.67	.41	.36	.29	.07	-.02
Reference Book	.57	.35	.12	-.00	-.02	-.21
	10.39	3.50	1.65	.95	.81	.75

Varimax-rotated factor loadings	1	2	3	4	5	6	h_2
Writing a Letter	.18	-.12	.75	-.04	-.31	.18	.73
Raven's Matrices	.28	-.83	.03	.23	-.07	.02	.83
D 48	.31	-.68	.16	.10	-.09	-.11	.61
Addition	.74	-.19	.36	.24	-.02	-.10	.78
Multiplication	.82	-.14	.38	.06	-.05	-.17	.87
Substitutes	.64	-.09	.22	.08	-.12	.04	.49
Wirebending	.05	-.44	.26	.45	-.08	-.19	.51
Bender	.22	-.33	.19	-.04	-.29	.13	.30
NIIP	.21	-.55	.31	.29	-.23	-.34	.70
F 1	.10	-.56	.20	.07	-.47	-.09	.60
Gothenburg Box	.09	-.14	-.15	.76	.09	-.03	.63
Puzzles	.04	-.82	.08	.09	-.12	-.27	.78
DLS	.38	-.22	.76	-.02	.08	-.05	.77
Matrices II	.23	-.77	.24	.27	-.21	.09	.83
Combination of Numbers	.33	-.13	.13	.33	-.13	-.11	.28
Proof Reading	.54	-.05	.59	-.11	-.10	.03	.67
Reels	.04	-.34	.02	.57	-.37	-.15	.60
MP	.06	-.31	-.07	.19	.03	-.41	.31
Cube Counting	.17	-.19	-.07	.05	-.13	-.73	.62
Labyrinths	.22	-.31	.03	.16	-.50	-.23	.47
Opposites	.18	-.25	.75	.03	-.01	-.03	.65
R 16 C	.48	-.31	.08	.44	-.37	-.27	.73
Copying	-.03	-.66	.26	.05	-.14	-.27	.60
Surface Development	.03	-.76	.09	.35	.12	-.35	.85
Arithmetic	.78	-.31	.36	.02	-.14	-.18	.88
Draw a Man	.07	-.57	.39	-.08	-.30	-.01	.58
Reading Speed	.29	-.15	.84	.15	.07	.04	.84
Reference Book	.35	-.07	.57	-.00	-.19	-.13	.51
	3.72	5.47	4.14	1.93	1.32	1.46	

Loadings underlined are significant at the 1 per cent level.

rather than a more limited ability, and there may be reason to presume that an attitude makes itself obvious in behaviour on several different levels.

In the analyses of the combined groups of deaf subjects (1965 and 1967), divided into boys and girls, the results in the group of girls gave a factor structure with a stronger link between the numerical, verbal and reasoning tasks than was found in the boys' group. A five-factor solution of the girls' results gave :

I. Symbol factor.

II. Spatial-inductive factor.

III. Bi-polar factor with Bender at one antipole and Raven's Matrices and D 48 at the other. The factor cannot be defined, unless one chooses to call it an inductive reasoning factor.

IV. Perceptual speed factor.

V. Motor factor.

The analysis of the boys' results showed instead a stronger link between numerical, spatial and reasoning tasks. A six-factor solution gave the following factors:

I. Numerical.

II. Spatial-inductive, also with a significant loading on the pratical-mechanical test.

III. Practical-mechanical, which was dominated by dexterity tests and had become rather practical-manual.

IV. Verbal.

V. Undefined bi-polar factor with Bender at one antipole and the Practical-mechanical test at the other.

VI. Perceptual speed.

The separate analyses of the material obtained from the girls and boys produced differences in the factor pattern, which suggested essential differences in the structure of ability. In the girls'group, numerical and verbal tests were collected in one factor, while the boys'material produced rather well-defined numerical and verbal factors. The connection between verbal, numerical and reasoning tasks was substantially stronger for the girls than for the boys. For the boys, on the other hand, the link was stronger between numerical, spatial and reasoning tasks. The reason why no verbal factor was obtained for the girls, who were linguistically superior, could be that the linguistic ability forms the core of the girls' intellectual equipment. Correspondingly, the core of the boys'intellectual equipment would be the spatial talent.

It was only in the analysis of the groups divided according to sex that Bender showed a tendency to appear in isolation in the factor structure. One possible interpretation of this could be that Bender measures different character traits in girls and boys, another that the trait measured by Bender has different effects on the behaviour of girls and boys. What Bender measures in the deaf group has strictly speaking not been possible to identify. In the separate analyses of the boys' and girls' results it appears in isolation in the factor structure and in the other analyses it produces no significant loadings.

The results from the analyses of the girls' and boys' groups must be regarded as tentative, since possible differences in the ways the tests were administered leave a combination of data from the two years (1965 and 1967) open to criticism. Since this study is more or less explorative, however, it is sometimes necessary to waive the demand for exactness in the methods used. The main issue is to try to shed light on all phenomena and lay a foundation for hypotheses, for which evidence can be obtained in later studies. The principal value of the separate analyses is that tendencies have emerged, which suggest that there might be essential differences in the structure of ability between girls and boys in the deaf group. As far as these results agree with those obtained in other studies, certain conclusions may more safely be drawn. Juurmaa (1963) found in his group of deaf girls a stronger link between numerical and verbal tests than in his group of deaf boys. Myklebust (1964) observed differences in results between deaf girls and boys, which he interpreted as being based on differences in the thought processes. Dissimilarities in the ability structure have also been noted in groups with normal hearing (Björsjö, 1951; Werdelin, 1961). Tyler (1965) provides a survey of differences between the sexes as far as the structure and organisation of various character traits are concerned.

The deaf boys did not score higher than the girls in spatial tests - there are, however, no consistently significant differences in level in hearing groups either. It is possible that the schools for the deaf have a bottom layer of boys with generally weaker results, who form a group with more intricate problems. But if the assumption is correct that spatial ability represents the core of the boys' intellectual equipment, then the boys at schools for the deaf must be at a considerable disadvantage. Because of the pupils' linguistic handicap, the teaching at these schools naturally has a strong bias towards the training of linguistic ability, which means a systematic training of an ability which might well be the asset of the girls, while spatial ability, which might be the boys' main asset, is more or less ignored in the teaching.

It is conceivable that, by supplementing the teaching at schools for the deaf with more concrete, manipulative material and visual aids, problem-solving and mathematic ability could be developed to a higher level, especially among the boys. This is not a problem which is restricted to the deaf. For the deaf, however, it is vital that existing aptitude for occupations in the technical and constructive line are stimulated and developed, since this can lead to well-paid trades, where the deaf can hold their own in competition with others. In linguistic ability the deaf can never compete.

A more detailed report of the research presented in this paper is available in Swedish (Nordén, 1969).

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Abstract card

Nordén, K. The structure of abilities in a group of deaf adolescents. Educational and Psychological Interactions (Malmö, Sweden: School of Education), No. 32, 1970.

Prelingually deaf adolescents (average age 15 years) were studied, in order to develop methods for psychological assessment of deaf subjects. Factor analyses were carried out on results from the girls' and the boys' groups separately and for the total group on data from the same tests, administered with and without speed limits. The results showed that speed is a variable that can have considerable influence on the factor structure. The separate analyses of the material obtained from the girls and the boys produced differences in factor pattern wich suggested essential differences in the ability structure.

Indexed:
1. Deafness
2. Ability testing
3. Factor analysis

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