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DEVELOPMENT AND VALIDATION OF THE HIGH LEVEL FIGURE CLASSIFICATION TEST

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NATIONAL INSTITUTE FOR PERSONNEL RESEARCH
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ND VALIDATION
EVEL FIGURE
N TEST

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This report describes some of the work done to date on project 60/23, "Revision and Extension of Tests".

The project was directed by Dr G K Nelson, Director of the National Institute for Personnel Research.

SUMMARY

This report describes the history, construction and validation of the High Level Figure Classification Test. The test was classified by the Test Commission as an 'A' level test in September, 1982.

The High Level Figure Classification Test went through three major stages in its development. In this process the number of items was reduced from 54 to 36 and finally to 24.

Detailed analysis of the High Level Figure Classification Test was carried out on ten samples representative of the population groups for which it is intended. This process is described with particular reference to the main analyses - item analysis and item response evaluation.

The merits of the High Level Figure Classification Test as a selection instrument are discussed.

OPSOMMING

Hierdie verslag beskryf die geskiedenis, konstruksie en geldigheidsbepaling van die Hoëvlak Figuurindelingstoets. Die toets is in September 1982 deur die Toetskommissie as 'n 'A'-vlak toets geklassifiseer.

Die Hoëvlak Figuurindelingstoets het deur drie belangrike ontwikkelingstadia gegaan. Tydens hierdie proses is die aantal items verminder van 54 tot 36 en uiteindelik na 24.

Deeglike ontledings van die Hoëvlak Figuurindelingstoets is uitgevoer op tien steekproewe wat verteenwoordigend is van die populasiegroepe waarvoor dit bedoel is. Hierdie proses is beskryf met besondere verwysing na die hoofontledings - itemontleding en itemrespons-evaluasie.

Die voortreflike hoedanighede van die Hoëvlak Figuurindelingstoets as 'n keuringsinstrument is bespreek.

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1.0 INTRODUCTION

Ever increasing numbers of Blacks are receiving secondary school education. The surge in the educational level of Blacks over the past 10 years has created a demand for psychological tests to assess the cognitive abilities of Blacks with secondary school education.

The NIPR reacted to this demand in 1974 when development began on the Figure Classification Test, a non-verbal test of concept formation. The test was published in 1976 (see Taylor, 1976) and was designed for use in the Standard 5 - 8 range.

The Figure Classification Test was 'pitched' at this educational range because of the rapidly rising numbers of Blacks who were starting to go to high school. At that stage, few Blacks reached or went beyond Standard 8, however (van Rensburg, 1975).

In the past few years, this picture has begun to change. Since 1979, there have been annually more than 100 000 Blacks in Standard 8 alone and in 1981, there were 136 000. This should be compared with the 1971 figure of 30 000. Over the 10-year period 1971 - 1981, the number of Blacks in matric has increased tenfold, from 4 100 to 43 600. Figures 1 and 2 present graphs of numbers of Blacks in Standard 8 and matric over the 1971 - 1981 period. These statistics were drawn from the Report of the National Manpower Commission for the period 1 January - 31 December 1981.

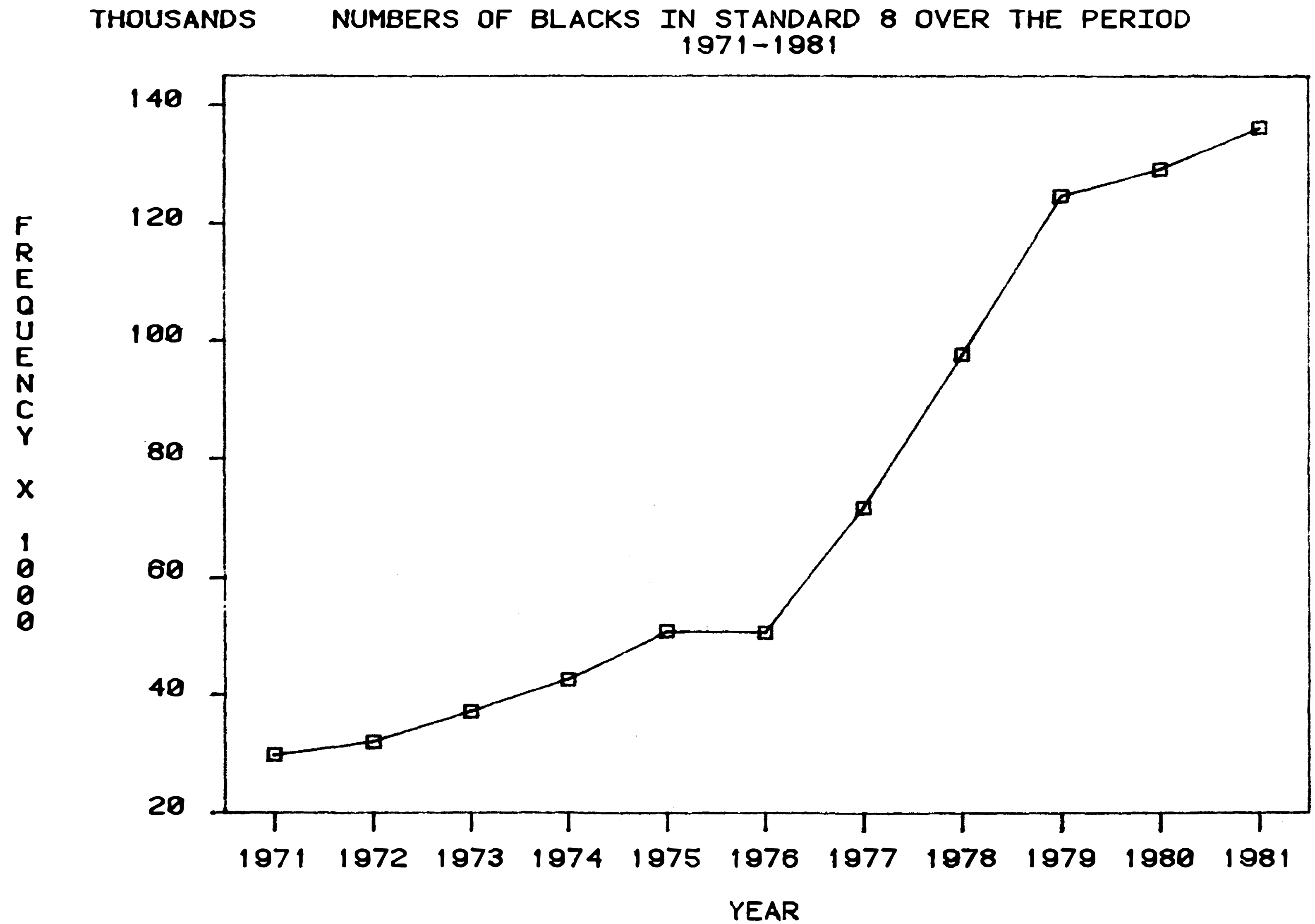

THOUSANDS
NUMBERS OF BLACKS IN STANDARD 8 OVER THE PERIOD 1971-1981
FREQUENCY X 1000
140
120
100
80
60
40
20
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
YEAR

Figure 1

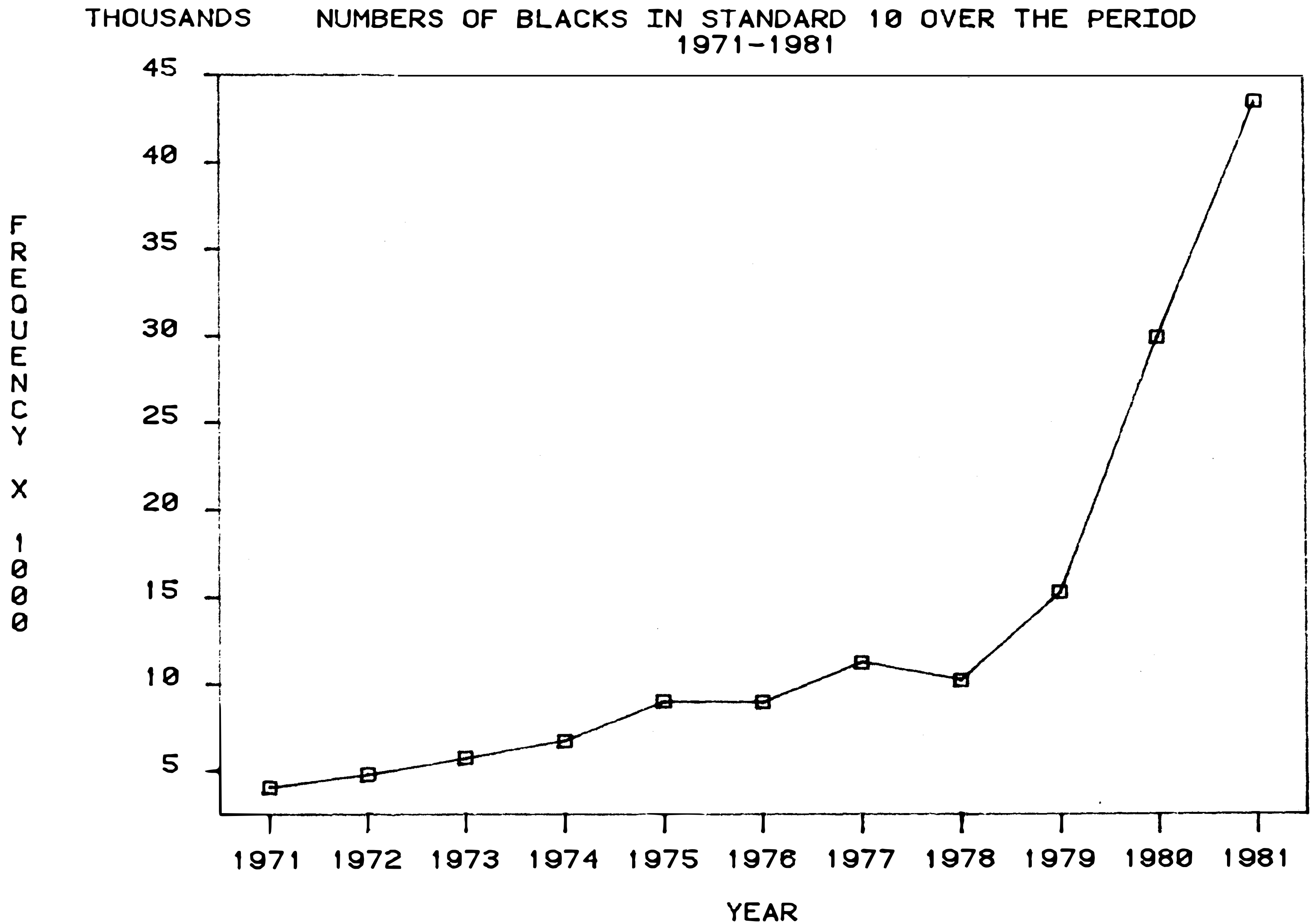

THOUSANDS
NUMBERS OF BLACKS IN STANDARD 10 OVER THE PERIOD 1971-1981
FREQUENCY X 1000
45
40
35
30
25
20
15
10
5
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
YEAR

Figure 2

Tables 1 and 2 show that the numbers of individuals in Standard 8 started climbing sharply from 1976. For individuals in Standard 10, the sharp rise occurred, not unexpectedly, two years later in 1978.

Although a much smaller proportion of Blacks reach Standard 8 than Whites, in absolute terms Blacks outnumber Whites in Standard 8. In 1981 there were 136 216 Blacks and 72 835 Whites in this standard. In matric, Whites slightly outnumbered Blacks in 1981: the numbers were 55 667 and 43 556 respectively.

These figures should have made it clear that a definite need exists for cognitive tests for Blacks with Standard 8 and upwards. The number of Blacks with at least 10 years of education entering the job market each year is substantial and in all likelihood will grow considerably in future years. The need for selection and placement instruments will grow accordingly.

In certain cases, tests originally designed for Whites can be used with success on Blacks. For instance, the NIPR regularly uses the spatial 'Blox' test on Blacks with at least Standard 8. On the other hand, the NIPR's tests of general intellectual ability (the various levels of the Mental Alertness) have not always proved to be totally satisfactory for application to Blacks (Hall, 1978). Visser (1978) obtained a mean score of only 16,95 on a sample of 101 first year Fort Hare students on the High Level Mental Alertness Test (which has a maximum possible score of 42). Scores were bunched at the lower end of the scale and the test's KR21 reliability index of 0,72 was lower than is commonly reported for White samples. The reliability of the NIPR's High Level Reading Comprehension test based on the Fort Hare sample was exceedingly low, with a KR20 of only 0,32. The reliability of the Vocabulary test was even lower.

These results suggest the need for a non-verbal test of general intellectual ability suitable for application to Blacks with higher levels of education. In many selection and placement contexts, it is desirable to have an index of a subject's ability to form concepts and reason abstractly uncontaminated by verbal skills. In tests like the Mental Alertness, the processing of verbal material forms an important component of the test task. Blacks, whose home language is not English or Afrikaans, might have difficulty in understanding what is required of them in certain items. In addition, many items in Mental Alertness - type tests require verbal reasoning. A task of this type is clearly more taxing for a subject whose home language is not the language of the test, for the subject either has to translate the material into his own language before performing logico-verbal manipulations, or perform these manipulations in a second or third language.

A further problem with the use of Mental Alertness - type tests on cultures for which they were not originally intended, is that these tests often have items which are strongly culturally bound. The items frequently have a scholastic flavour about them. As the quality of Black education is generally inferior to that of White, it is not surprising that Blacks have more difficulty doing Mental Alertness - type tasks than Whites. School education is done largely in a verbal medium: concepts are taught through the use of words and logical symbols. Seldom is a pictorial or diagrammatic medium used. The use of a diagrammatic format for a test of reasoning ability or concept formation has the advantage that the scholastic component in the test is reduced as the mode of presentation is not typically scholastic.

Although this scholastic component in a psychological test can be reduced, it generally cannot be eliminated. Concepts taught in school appear in psychological tests, and individuals who have had less, or poorer quality schooling, can be expected to do more poorly on the tests than those who have had more education or a better quality of it. Nor is it desirable to attempt to eliminate the scholastic component in psychological tests by using concepts which are not taught in Western-type educational institutions. Most tests are used for selection and placement; the ability to recognize and use the sorts of concepts which are taught at school and university probably contribute significantly to the predictive validity of tests . South Africa is becoming ever more strongly a member of the Western-technological community of nations; in order to be valid, psychological tests must incorporate concepts which are necessary for effective functioning in a Western-technological society, if these tests are to be used for selection and placement in the work environment. On the other hand, efforts should be made to eliminate material from a test which is culture-bound and also has no predictive validity. Material of this kind is unfair in the profoundest sense of the word to those individuals who do not belong to the culture in which the test is sourced, especially if the same test is being used to select individuals from different cultural and/or racial backgrounds. It is in an effort (partially) to avoid this problem than the NIPR adopts the policy of having differential norm groups; norm groups are fairly precisely described in terms of race, sex, age, education and work field. This makes it possible to rate an individual against his peers (as defined in the norm-group description), but problems arise when an evaluation across groups is required.

This is a common problem in the practical situation of hiring job applicants or selecting individuals for training inputs. Ultimately, the concern is to select people who are capable of handling the intellectual demands placed on them on the job or training course. This is a problem even when the population to be selected from is homogenous; if the selection population is heterogeneous, the problem is exacerbated. There is no perfect solution to this problem. The best compromise is to determine separate minimum scores for each norm population such that individuals above that score have a reasonably good chance of being successful in the activity for which selection is being used and those below the score are unlikely to be intellectually equipped for the pursuit in question.

The above procedure involves a large amount of validatory work, ideally performed specifically for each selection application. In addition, the problem remains that the test in question might prove to be more valid for the selection of one type of applicant than another. If this problem is severe, it will be necessary to use different tests for different applicant populations.

The High Level Figure Classification Test is a new instrument which in many cases will be a suitable measure to use in the selection of Blacks, Coloureds and Indians with the appropriate educational background for work and training courses which involve a fair amount of conceptual activity. It will give an index of the individual's general intellectual ability uncontaminated by verbal skills. At the job and educational levels where the HL FCT is likely to be used, verbal skills are often important in the successful accomplishment of the tasks in hand. In many cases, therefore, it will be appropriate to apply at least two tests to subjects: the HL FCT and a verbally-based test. (In some instances, yet other tests would be appropriate: for instance a test of number ability or spatial ability if the nature of the work warrants it).

This multitest approach will enable a more accurate assessment of the individual's capacities to be made. When a verbally presented intelligence test is employed, a low score might indicate low verbal skills or poor conceptual ability, or both. The use of an FCT-type test allows conceptual ability to be measured more purely. If verbal, numerical or any other ability is important in the tasks which successful applicants will be required to do, these can be assessed with separate instruments.

As the test uses diagrammatic stimulus material which is likely to be more-or-less equally unfamiliar to all cultural and racial group, it is hoped that the problem of different validities for different types of subjects will be minimized in most applications. The need, however, to establish appropriate selection cut-offs for particular applications, remains.

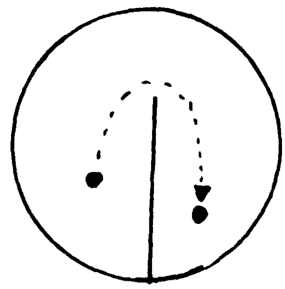
2.0 BACKGROUND TO THE DEVELOPMENT OF THE TEST

The High Level Figure Classification Test (HL FCT) is very similar to the standard FCT, both in concept and in item format. The main difference between the tests is that the HL FCT is designed to be used on a more highly educated group (individuals with at least Standard 8).

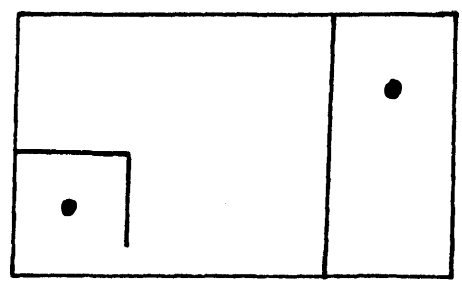
Each item is printed on a separate page; the subject's task is to divide six diagrams into two groups of three so that the diagrams in each group share some feature in common. In easier items, the similarities usually are perceptually apparent, whereas in the more difficult items, the similarities are conceptual. No simple dichotomisation into perceptual and conceptual can be made; rather perceptual and conceptual should be seen as opposite ends of a continuum.

Even in the more perceptual items, there is still a substantial conceptual element. In one of the easier items of the standard level FCT, for instance, each of the six diagrams incorporates figures which either decrease in size from left to right, or increase in size from left to right. The subject has to classify the diagrams into 'increasing' and 'decreasing' categories. Although increasing or decreasing size is perceptually apparent, the testee has to overcome distracting influences (such as different shapes and shadings of the diagrams) in order to identify the relevant concepts.

In most of the items of the HL FCT, the testee receives very little assistance from perceptually obvious cues. He has to look beyond the shapes of the diagrams in order to ascertain the underlying concepts. Let us illustrate this by taking one of the more difficult items in the HL FCT, one which embodies the notion of 'path-connectedness'. Two points are path-connected if they can be joined by a line without passing through any barrier, e.g. :



The following points on the other hand are not path-connected:



A set of path-connected diagrams can vary enormously in physical appearance and yet all embody the same concept. Similarly, a set of non-path-connected diagrams can differ enormously in appearance.

Up to this point, we have been using a number of terms to describe the task-required in the FCT tests: concept formation, categorization, conceptual functioning etc. Cattell's (1971) term 'fluid intelligence' might also be used to describe the test task. To these we will add one more which we think underlies all these activities: abstraction.

The notion of abstraction has a long history. Aristotle refers to it is his Metaphysics and defines it as the process of disregarding the particular in order to extract what is common. In psychology, the ability to categorize has often been associated with abstracting activity, because by forming a class or category of objects or phenomena one is finding an underlying similarity between these objects while disregarding aspects of dissimilarity.

In Western civilization, the ability to abstract is highly regarded and many psychologists would see it as the basis of intelligent behaviour. It is hard to imagine the development of Western culture without simultaneously thinking of abstraction. Spengler (1926) believes that polyphonic music and the mathematics of functional relationships are the greatest achievements of modern Western culture (which he sees dating from about 1 000 A.D. to the present). Both of these disciplines are highly abstract. Compare for instance the classical mathematics of Euclidean geometry with calculus. In Euclidean geometry, the relationships are fixed (pi, for instance) whereas in calculus, the unknowns in an equation are variable. Variables are highly abstract concepts. It is impossible to conceive how the scientific, philosophical and technological successes of Western civilization could have been achieved without ability to function abstractly. One must remember, however, that abstractions or concepts are arbitrary. Cultures form concepts which are useful in ordering their work and social experiences. In categorizing, one is choosing to highlight certain characteristics while ignoring others.

The converse of abstract thinking is usually called concrete thinking. Thinking of this kind has often been associated with 'primitive' or childish states (e.g. see Lévy-Bruhl, 1923). Some authors (e.g. Cryns, 1962) see African culture as being highly concretisic in its thought patterns. Much of this type of commentary can be accused of cultural chauvinism. Up to the middle of this century statements about the concreteness of thinking of certain non-Western peoples were frequent and laden with negative value judgements (see Werner, 1948 and Carothers, 1953). Authors who made these statements tended to assume that tests designed for Western subjects were quite suitable for application to Blacks and would not have any adverse effect on performance. In many cases, no words existed in subjects' native language for certain features of the test stimuli which they were required to handle. Subjects in many cases had absolutely no formal education and came from cultural environments which were almost totally untouched by Western thought.

Johoda (1956) was the first to point to the inadequacies of indiscriminately using Western-designed tests to assess conceptual functioning of non-Western people. He found that a group of non-Westernised illiterate Africans performed significantly worse on a measure of abstract behaviour than a group of relatively more Westernised literate compatriots. Later studies have confirmed this finding (Price- Williams, 1962; Ciborowski and Serpell, 1971, Aborowski and Cole, 1971; Kellagahan, 1968; Okonji, 1971; Irwin and M^c^Laughlin, 1970).

Two other points about the supposed inability of illiterate non-Westernised people to make abstractions will be made here. Firstly it is possible that these people only appear to be concretistic in their thought patterns because they have not been tested on culturally relevant classificatory tasks. Some support for this comes from Okonji (1971) and Price-Williams (1962). Secondly, even if it were possible to establish objectively that certain non-Western cultures are indeed more concretistic, it is a value judgement to say that this type of thinking is unavoidably inferior to abstract thinking. Certainly it is inferior in the context of operating effectively in a Western-technological environment, but it might not be inappropriate in other contexts; in fact it might be beneficial and adaptive in certain cultures. Far from being primitive, the ability to make fine discriminations between objects may be regarded as a demanding cognitive skill. Even in Western society, the previously unquestioned basic tenet of logical and scientific thought that parsimony and generalizability are to be sought at all costs is coming under fire from some critics. These critics would have the Western penchant for classification and reduction tempered with a more holistic orientation, the rationale being that in reducing an object or phenomenon to its constituent parts and classifying it, important uniquenesses of the whole are lost, ignored or distorted. Despite these criticisms, however, it is almost unthinkable that Westerners will completely abandon the logical and scientific cutting tools of classification and reduction, which have served them so well in the building of their materially successful technological society.

The abstraction and classification tasks with which the Figure Classification Tests confront subjects can be seen as closely related to tasks which are continually required of people working in a technological society. The activity of abstraction/classification involves both analytic anc synthetic elements. The FCT and HL FCT require these functions in the order: analysis, synthesis, analysis (ASA).

Analysis (1)	The subject first has to scrutinize the stimulus material and take note of the precise shapes and components of the diagrams.
Synthesis	The subject then has to form hypotheses concerning the concepts which are embedded in the item. This is the abstracting phase.
Analysis (2)	Finally, the subject has to check whether his hypothesis is valid. In particular, he must determine whether there are three representatives of each concept to that he can achieve the requirement of splitting the six diagrams into two groups of three.

In many real-life tasks in Western society, successful functioning is dependent on the application of an ASA procedure. The individual has to analyse the complex of phenomena, classify the phenomena into one or more conceptual classes, then check whether his classification is a useful and effective one for the situation at hand.

Classification or abstraction can be seen as an information reduction task (Posner, 1964). It is a "many-to-one" mapping. Many objects, events or phenomena are mapped into a single conceptual class, as apples, pears, grapes, etc. can be mapped into the single class of fruit. Inevitably, much information is lost in this process. However, if classification is appropriately used, the gains in conceptual economy outweigh the losses of specific information. Information reduction classification is essential in Western-technological society for the following reasons:

1) Information input is at a very high level in technological society; the individual has to classify, simplify and generalize in order to avoid being swamped by masses of specific information.

2) Classification is essential to building up a repertoire of appropriate responses to input stimuli. People are confronted every day with stimulus complexes differing in various ways from situations which they have encountered in the past. The ability to take out the essence, to say: "This is an 'abc' type situation and hence the best way to handle it is to do 'xyz'" is essential if one is to be able to put past experience of successful behaviour to use in present and future situations.

The HL FCT is considered to be a suitable measure for identifying individuals who will be required to perform work which is not repetitive, which involves taking decisions without constant reference to a superior and which requires the incumbent to structure his tasks in order to manage them effectively.

3.0 STAGES IN THE CONSTRUCTION OF THE HIGH LEVEL FIGURE CLASSIFICATION TEST (HL FCT)

This chapter describes the construction and refinement of the High Level Figure Classification Test (HL FCT).

The HL FCT was originally constructed with 54 items. This version was then modified and an improved version of 36 items was produced. After extensive analysis, the test was further modified and shortened to 24 items. This 24 item version was classified by the Test Commission as an 'A' level test in September, 1982.

During the three stages of construction and refinement of the HL FCT and its subsequent evaluation, ten samples of Asian and Black subjects with 10 to 12 years of education were tested. These samples are listed below:

i) Black employees of a construction company (n=97)
ii) Asian employees at an insurance company (n=87)
iii) Black nurses at Baragwanath Hospital (n=451)
iv) First year Fort Hare students (n=145)
v) Asian apprentices in the mechanical trades of the sugar industry (n=93)
vi) Black apprentices in the mechanical trades of the sugar industry (n=165)
vii) Black male applicants for technical training (n=263)
viii) First year Mabopane East Technikon students (n=199)
ix) Black male work-seekers who approached the work orientation centre of the Orange-Vaal Adminstration Board (n=126)
x) Sowetan pupils in Standard 8 doing mathematics and science (n=127)

Detailed analysis and evaluation of the above data resulted in the final 24 item version of the HL FCT. The main analyses were item analysis and item response evaluation (see 3.1).

In order to explain the uses of the two programmes, the output statistics of the programmes will be discussed in detail. The data presented for discussion is that of the first sample analyzed, the 97 Black employees of a construction company.

3.1 ANALYSES PERFORMED ON THE 54 ITEM VERSION OF THE HL FCT.

The three versions of the HL FCT were subjected to in-depth analysis. The two programmes used extensively were the NIPR's NP77-A (Coulter, 1973) and NP50 (Maughan-Brown, 1973).

NP77-A, known as the Item Response Evaluation (IRE), was used for evaluating the test as a whole, each individual item and the alternatives within each item. NP50 is an item analysis programme designed for item selection. It was thus used as an aid in choosing the subset of items that made the HL FCT optimal in terms of reliability and distribution form.

Both these programmes have several important features only some of which were relevant to the analysis of the HL FCT.

Only these relevant features will be discussed here. For further information on the programmes, the programme manuals should be consulted (Coulter, 1977; Maughan-Brown, 1973).

3.2 THE NIPR'S NP77-A ITEM RESPONSE EVALUATION PROGRAMME

The NP77-A or the IRE was used for evaluating:

i) the test as a whole
ii) each individual item
iii) the alternatives within each item

Each of the above will be considered in turn.

ITEM: 18

No. Attempting = 89 Proportion Attempting = 0,92

Alternative	Omit	1	2	3	4	5	6	7	8	9	10
Prop Endorsing		0,3258	0,0112	0,0112	0,0337	0,0449	0,3034	0,1124	0,0	0,1461	0,0112
Prop Endors Incl Omit	0,0825	0,2990	0,0103	0,0103	0,0309	0,0412	0,2784	0,1031	0,0	0,1340	0,0103
Std. Dev.	0,2751	0,4578	0,1010	0,1010	0,1731	0,1988	0,4482	0,3041	0,0	0,3407	0,1010
Criterion: Key											
Prop Corrected For Guessing		0,2509	0,0125	0,0125	0,0375	0,0499	0,3371	0,1248	0,0	0,1623	0,0125
Mean	26,0000	21,2758	7,0000	30,0000	18,0000	19,2500	23,0370	22,2000	0,0	22,6154	8,0000
Correl. With Crit.	0,1405	-0,1064*	-0,1661	0,0929	-0,0739	-0,0572	0,0880	0,0167	0,0	0,0374	-0,1548
Reliability Index	0,0361	-0,0257	-0,0172	0,0091	-0,0139	-0,0128	0,0304	0,0017	0,0	0,0084	-0,0160
Discrimination Index	0,1419	-0,1070	-0,1684	0,0933	-0,0742	-0,0573	0,0883	0,0167	0,0	0,0375	-0,1567

TABLE 2: Display of IRE Statistics of Item 18 which was dropped from the HL FCT

ITEM: 20

No. Attempting = 94 Proportion Attempting = 0,97

Alternative	Omit	1	2	3	4	5	6	7	8	9	10
Prop Endorsing		0,0532	0,0319	0,0532	0,0319	0,0319	0,6915	0,0213	0,0426	0,0426	0,0
Prop Endors Incl Omit	0,0309	0,0515	0,0309	0,0515	0,0309	0,0309	0,6701	0,0206	0,0412	0,0412	0,0
Std. Dev.	0,1731	0,2211	0,1731	0,2211	0,1731	0,1731	0,4702	0,1421	0,1988	0,1988	0,0
Criterion: Key											
Prop Corrected For Guessing		0,0591	0,0355	0,0591	0,0355	0,0355	0,6572	0,0236	0,0473	0,0473	0,0
Mean	13,0000	11,4000	13,6667	9,8000	8,6667	17,3333	26,0923	17,5000	20,7500	15,2500	0,0
Correl. With Crit.	-0,1714	-0,2664	-0,1578	-0,3091	-0,2600	-0,0828	0,6054*	-0,0645	-0,0150	-0,1456	0,0
Reliability Index	-0,0310	-0,0608	-0,0287	-0,0699	-0,0459	-0,0162	0,2999	-0,0104	-0,0059	-0,0311	0,0
Discrimination Index	-0,1740	-0,2763	-0,1598	-0,3250	-0,2693	-0,0831	0,7606	-0,0646	-0,0150	-0,1471	0,0

TABLE 3: Display of IRE Statistics of Item 20 which was retained for a further version of the HL FCT

Tables 2 and 3
are contained
overleaf.

Please turn over
and open.

3.2.1 TEST CHARACTERISTICS

Table 1 is a display of the test characteristics supplied by the IRE.

NO. ITEMS	MEAN	STD. DEV.	OMISSION RATIO	K-R 20(1)	K-R 20(2)
54	22,05	9,0754	0,0851	0,8829	0,9002
K-R 20(1) : No response taken as wrong K-R 20(2) : No response taken as missing information					

TABLE 1: Statistics Computed by the IRE of the HL FCT as a Whole

The IRE computes the mean and standard deviation of the test. These statistics are some of the indicators of the applicability of the test to the sample tested. The mean provides some information on the difficulty of the test items, the homogeneity of the sample and amount of error variance in the test (Coulter, 1977; pp 20 - 21). For the HL FCT a standard deviation of 9,1 shows that there is a satisfactory spread of scores across the sample.

The Kuder-Richardson reliability coefficient K-R 20 is an index of the internal consistency of the test; it takes into account the correlation of each item with the total test score. In general, the test constructor is satisfied with coefficients of 0,75 and above. A low coefficient of internal consistency may indicate that the test is composed of more than one dimension. The IRE computes two values for the coefficient of internal consistency. K-R 20(1) is calculated under the assumption that any items omitted by the respondent could not be done and are thus wrong. K-R 20(2) assumes that omissions are really unattempted items and should therefore be taken as missing information. Since the HL FCT is considered to be a power test with little or no speed variance, ample time is given to the testee to complete the test.

Thus the first measure of K-R 20 is more appropriate. The HL FCT has high internal consistency (0,88) for the sample tested, taking omitted items as wrong.

Finally, the omission ratio computed by the IRE shows the average proportion of omissions per item. This ratio should always be very low for accurate estimates of the reliability coefficient. For the HL FCT, the omission ratio of 0,08 was considered sufficiently low.

3.2.2 ITEM STATISTICS

The statistics of the 54 item HL FCT considered as a whole seemed satisfactory. The test however was much too long. The next step was thus to examine carefully the statistics of each item and to assess whether or not it should be retained in a shortened version of the test, or discarded. In addition to the statistics description above, the IRE provides information on each alternative of every item.

Two items from the original HL FCT have been selected to illustrate the item statistics provided by the IRE. These are displayed in Tables 2 and 3. The relevant parts of these displays have been enclosed in boxes. Table 2 presents statistics on item 18, an item which was dropped from the test; Table 3 shows the statistics for item 20, which was retained.

The IRE computes the number (and proportion) of people who have attempted each item. For items 18 and 20 of the HL FCT, there was a high proportion of endorsements (0,92 and 0,97 respectively). Accurate item statistics can be obtained when item endorsement is high and the sample is large. If a very low number of people endorse an item, it may mean that the item looks difficult to the testee and large number of people do not attempt it for this reason. Such an item should be modified or dropped from the test. If there are items with high proportions of omissions at the end of the test, it may mean that the subjects did not have enough time to complete the test. In such a case, lengthening the time limit may be advisable.

The item mean is given by the proportion of respondents endorsing the correct alternative. In the IRE printout, the column containing the statistics for the correct alternative is indicated by an asterisk. The correct alternative has been boxed in Tables 2 and 3. The item mean is an indication of the difficulty level of the item. The mean for item 18 is 0,3 and for item 20 is 0,67. Item 20 is therefore a much easier item than item 18. For a discussion of proportions see page 21.

The item standard deviation is a function of the mean and should, in most cases, not be small since this will limit the total test variance. An exception is when the test is to be used to discriminate at a very high level. In such a case large numbers of items with very high means are appropriate even at the cost of reducing item standard deviation and hence test variance. An example of such a situation is when the tester wishes to select only "best" people i.e., those at the top extreme of the test score distribution. On the other hand, a number of items with very low means would be chosen if the tester wishes to screen out only those people at the lower tail of the distribution (see 3.2.2 for a discussion of test score distribution).

For a dichotomous test, the standard deviation of an item is computed as follows:

$$S_i^2 = P_i(1 - P_i)$$

Where:-
S_i^2 is the variance of item i
and P_i is the mean of item i or the proportion of respondents endorsing item i correctly

The maximum possible values of the standard deviation and variance of a dichotomous item are 0,5 and 0,25 respectively. These values are attained when half the respondents answer the item correctly.

Both items 18 and 20 have high standard deviations (0,46 and 0,47 respectively).

3.2.3 CHARACTERISTICS OF ALTERNATIVES

Up to this point, the overall test characteristics have been discussed and statistics on the two example items of the HL FCT have been examined. Careful examination of the statistics of the alternatives is also necessary as this might reveal problems with one or more of the alternatives. The IRE provides information on every legitimate way in which the testee can respond.

The HL FCT is a test in which the respondent must group 6 different figures into 2 groups with 3 figures in each. The total number of possible ways of doing this is calculated as follows:

$$^{n}C_{r} = \frac{n!}{r!(n-r)!} \quad \text{............ Equation (1)}$$

Where:-
n denotes the total number of different objects
and r denotes the number of objects being selected

For the HL FCT we substitute the values n=6 and r=3, and further divide by 2 since 2 groups of 3 objects each are being selected at once.

Substituting in equation (1) above and dividing by 2, we obtain:

$$\frac{^{6}C_{3}}{2} = \frac{6!}{3!(6-3)!2} = 10$$

Thus there are ten possible ways of responding to any given item of the HL FCT. The IRE provides statistics relating to each of these ten individual alternatives.

An important statistic for the test constructor to examine is the proportion of people in the sample endorsing each alternative. Since there is only one alternative considered correct for each item of the HL FCT, there are nine other alternatives all of which may be thought of as distractors. The test constructor should be suspicious of any item in which the percentage of respondents choosing the alternative designated correct is lower than that for one or more distractors. Such results may be caused by lack of clarity in the item such as unclear diagrams.

On the other hand, if the distractors of an item lack credibility, few or none of the respondents will endorse them and the probability of guessing the correct answer may be increased. Transparently incorrect alternatives should thus be reviewed or the item should be replaced.

Thus a good item is one where the proportion of respondents endorsing any of the distractors is neither higher than the proportion endorsing the correct alternative, nor near zero.

The IRE provides three sets of proportions of endorsements on the alternatives of each item.

i) proportions excluding omissions
ii) proportions including omissions
iii) proportions corrected for guessing

The first set of proportions is most appropriate when omitted items are taken as missing information rather than as incorrect responses. As discussed earlier, any items omitted from the HL FCT were considered to be wrong rather than unattempted. Consequently, the set of proportions including omissions is appropriate for the test.

The IRE provides an estimate of the proportion of testees who really know the correct answer. This estimate attempts to exclude those individuals who guessed the correct answer. This third set of proportions is computed under the assumption that testees who do not know the answer guess randomly (see Coulter, 1977; pp 27 - 29). Thus the corrected proportion endorsing the correct alternative will be deflated while the corrected proportions endorsing the distractors will be slightly inflated.

Let us return to Table 2 and examine the proportion of the respondents (including omissions) endorsing the alternatives of item 18. Only 0,3 or 30% of the respondents endorsed the alternative designated correct. In itself, there is nothing alarming about this figure; however on further examination, it can be noticed that approximately 0,28 or 28% of the respondents endorsed the 6th alternative. After correction for guessing an even worse picture emerges: the 6th alternative was endorsed more often than the 'correct' alternative, and there was little endorsement of 6 of the other 8 distractors. In such a case there may be ambiguity or there may be an alternative correct response. A characteristic of tests like the HL FCT which involve inductive tasks is that there is no unique correct answer. The test constructor goes out of his way to build a salient concept into each item. If he does not succeed in his aim, respondents might find another 'correct' answer.

The distribution of responses across the alternatives of item 20 (Table 3) looks better. While approximately 0,66 or 66% of the respondents endorsed the correct alternative, more or less equal proportions of the respondents endorsed the distractors. This shows the absence of both ambiguity and alternative correct solutions to the item.

Once the test constructor has looked at the distribution of responses across the alternatives, he should see whether the 'brighter' people in the sample are endorsing the correct alternative. By inspecting the average score on the whole test of those respondents endorsing each alternative, it can be seen which alternative is being endorsed by the 'brighter' respondents. This average test total is given by the IRE as the mean for each alternative.

For a good item, the correct alternative should be endorsed by the brighter people and have a mean (or average test total) which is higher than that of any of the distractors.

If the 'bright' people or those who do well on the test endorse the correct alternative, this alternative will correlate highly with the test total and the correlation between the distractors and the total will be negative. Any item in which one of the distractors correlates more highly with the test total than does the correct alternative should be carefully inspected for ambiguity or an alternative solution apparent only to high scoring respondents. Items which are excessively easy or difficult may correlate near zero with the test total. Such items provide little discrimination between people and should be revised or discarded.

Examining item 18 (Table 2), one can immediately see the reason for dropping this item from the test. The mean for the alternative designated correct (21,28) is lower than that for several of the distractors, and the correlation for the 'correct' alternative with the total (or criterion) is negative (-0,11). This indicates that the people who scored well on the test as a whole did not endorse that alternative. Moreover, the correlations of the distractors with the total are often positive. These statistics show that there is something seriously wrong with the item.

On the other hand, the patterns of means and correlations of the alternatives of item 20 are quite different. The correlations of the correct alternative with the total is high (0,61) and those correlations between the distractors and the total are all negative. Such an item is valuable to include in the test.

Two further sets of statistics on alternatives are provided by the IRE for the HL FCT. These are the reliability index and the discrimination index. These indices however, were not the main criteria considered in the evaluation of the items of the HL FCT and hence will be discussed only briefly.

For the correct alternative, the reliability index gives an indication of the contribution of the item to the total test reliability. In order to obtain good discrimination between respondents, it may be necessary to include items which have relatively low standard deviations and lower reliability indices as a consequence. If these items have high correlations with the total, they should still be included in the test in spite of their relatively lower reliability index (Coulter, 1977).

If one examines the set of reliability indices for item 18, it can be seen that all these values are near zero. For the correct alternative, the reliability is near zero (-0,03) and lower than that of some of the distractors. The picture is once again different for item 20. The reliability index for the correct alternative is fairly high (0,3) and that for each of the distractors negative.

The discrimination index for the correct alternative is an estimate of the maximum discriminating power of the item. Loosely speaking, item discriminating power is an index of the effectiveness of an item in discriminating between "good" and "poor" subjects. The maximum discrimination takes place at a point that is a function of the proportion of respondents endorsing the item (Lord and Novick, 1968).

Returning once again to the statistics of items 18 and 20, it can be seen that the discrimination indices are consonant with other indices of performance for these items.

The discrimination index for the correct alternative of item 18 is negative (-0,11) and lower than that of most of the distractors; item 20 has high discrimination index (0,76).

In the above discission, only the statistics used in the construction and the refinement of the HL FCT have been reviewed. For a complete and more detailed discussion of the capabilities of the IRE see Coulter (1973).

The other programme used extensively in the refinement of the HL FCT is the NIPR's NP50 item analysis programme. The following section describes this programme as used for the HL FCT.

3.3 THE NIPR'S NP50 ITEM ANALYSIS PROGRAMME

Unlike the IRE which is intended for evaluating items individually and the test as a whole, the item analysis programme or NP50 is designed for item selection. It was thus used as an aid in choosing the subset of items that makes the HL FCT optimal in terms of reliability and distribution form. The programme can iteratively maximize the reliability of the test, dropping those items which fall below a specified criterion level until maximum reliability has been obtained. Once again, only the programme options used for the HL FCT will be described here. Further information may be obtained from the programme manual (Maughan-Brown, 1973).

For the original set of items as well as for each successive iteration, NP50 supplies the following:

i) test score statistics
ii) distribution form
iii) item-test correlations
iv) means and standard deviations of item statistics
v) reliability coefficients

3.3.1 TEST CHARACTERISTICS

In the case of a dichotomous (right-wrong) test such as the HL FCT, the NP50 programme required a key which indicates the correct response for each item considered. NP50 computes total test scores by counting the number of correct responses for each subject. It then calculates the mean and standard deviation of the test scores, giving the 95% confidence limits for both. Table 4 below is a display of these statistics for the HL FCT. It may be observed that the mean and standard deviation correspond to those in Table 1 since both programmes compute these statistics. As in the previous sections, all statistics quoted in this chapter are based on the sample of 97 construction workers.

N	MEAN	95% LIMITS OF MEAN	SD	95% LIMITS OF SD
97	22,052	20,222 - 23,881	9,075	7,953 - 10,569

TABLE 4: Test Score Characteristics of the HL FCT computed by the Item Analysis Programme (NP50)

3.3.2 DISTRIBUTION FORM

The programme supplies information on the form of the distribution of scores. A histogram of the scores is plotted and the maximum and minimum test scores and the score range printed. Table 5 below is a display of the distribution form of the scores as computed by the NP50 programme. If the maximum possible score is greater than 15, the scores are compressed into a 15 unit histogram labelled from 0 to 14.

DISTRIBUTION OF TEST SCORES		
0	0,667	
1	4,333	XXX
2	8,000	XXXXXX
3	7,667	XXXXX
4	9,333	XXXXXXX
5	12,000	XXXXXXXXX
6	19,667	XXXXXXXXXXXXXX
7	10,667	XXXXXXXX
8	10,667	XXXXXXXX
9	10,000	XXXXXXX
10	2,667	XX
11	1,333	X
12	0,0	
13	0,0	
14	0,0	
Maximum Test Score = 40 Minimum Test Score = 3 Range = 37		

TABLE 5: Distribution of Scores on the HL FCT computed by the Item Analysis Programme

The shape or form of the distribution is very important. The distribution shape is determined by the difficulty level of the items, the covariances among items, and the number of items (Nunally, 1978).

A distribution tends to be skewed whenever the test mean approaches scores on the upper or lower extreme of the distribution. Distributions which are positively skewed or skewed toward the upper end of the scale are often produced by tests with items that are relatively difficult. In such cases the majority of test scores are fairly low and thus the test mean is fairly low. Conversely, negatively skewed distributions are often produced when the respondents find the items relatively easy resulting in fairly high test total mean.

The test constructor may wish to construct a test with a distribution which approaches the symmetric bell-shaped curve of the normal distribution. However, in many cases a flattened normal or platykurtic distribution is desirable as tests with this type of distribution generally discriminate fairly well across the entire score range. Skewed distributions are nevertheless often useful for stringent selections of people at the extremes of the distribution.

The distribution of HL FCT scores in Table 5 is positively skewed. The mean score (22,05) is fairly low for a test of 54 items and no respondent scored higher than 40. This version of the test is thus fairly difficult for the sample concerned.

3.3.3 ITEM STATISTICS

The programme computes several item statistics which are useful to the test constructor in item selection and evaluation. These statistics are the same as those computed for the correct alternatives of each item by the IRE and hence will be discussed only briefly. In instances where the detail of the IRE analysis is not required, the summary form provided by the NP50 programme is sufficient.

The item statistics computed by NP50 include the following:

PJ the proportion of respondents who answered the item incorrectly

PW the proportion of respondents who answered the item correctly. Therefore PW = 1 - PJ

SJ2 the variance of the test totals of those respondents who correctly answered the item

SJ the standard deviation of the test totals of those respondents who answered the item incorrectly. SJ = SJ2

XBARJ the mean of the test totals of the respondents who correctly answered the item

RX the item-test point biserial correlation i.e., the correlation computed for all respondents between each person's score on the item and his test total. The point-biserial correlation is computed whenever there is one dichotomous variable (such as scores on a right-wrong item) and one continuous variable (such as test totals)

RXSJ Gulliksen's Index is the item-test point biserial correlation multiplied by the standard deviation of the item

ITEM-TEST CORRELATIONS

No. of Items in the Test Score = 54

ITEM	NJ	PJ	PW	SJ2	SJ	XBARJ	RXSJ	RX
1	41	0,423	0,577	0,244	0,494	25,854	0,178	0,360
2	41	0,423	0,577	0,244	0,494	28,000	0,278	0,564
3	64	0,660	0,340	0,224	0,474	25,906	0,282	0,595
4	50	0,515	0,485	0,250	0,500	27,180	0,293	0,586
5	48	0,495	0,505	0,250	0,500	27,604	0,304	0,609
6	57	0,588	0,412	0,242	0,492	25,860	0,248	0,504
7	64	0,660	0,340	0,224	0,474	25,656	0,263	0,556
8	74	0,763	0,237	0,181	0,425	25,203	0,266	0,626
9	80	0,825	0,175	0,145	0,380	24,563	0,229	0,603
10	44	0,454	0,546	0,248	0,498	27,886	0,293	0,589
11	74	0,763	0,237	0,181	0,425	25,446	0,287	0,674
12	38	0,392	0,608	0,238	0,488	24,447	0,104	0,213
13	38	0,392	0,608	0,238	0,488	25,395	0,145	0,297
14	52	0,536	0,464	0,249	0,499	26,058	0,238	0,477
15	75	0,773	0,277	0,175	0,419	23,653	0,137	0,328
16	47	0,485	0,515	0,250	0,500	24,319	0,122	0,244
17	33	0,340	0,660	0,224	0,474	27,303	0,198	0,418

TABLE 6: Item-test Correlations Computed by the Item Analysis Programme (NP50) on the HL FCT Data

ITEM-TEST CORRELATIONS

ITEM	NJ	PJ	PW	SJ2	SJ	XBARJ	RXSJ	RX
18	29	0,299	0,701	0,210	0,458	21,276	-0,026	-0,056
19	32	0,330	0,670	0,221	0,470	27,469	0,198	0,421
20	65	0,670	0,330	0,221	0,470	26,092	0,300	0,638
21	38	0,392	0,608	0,238	0,488	27,263	0,226	0,463
22	55	0,567	0,433	0,246	0,495	25,855	0,239	0,482
23	29	0,299	0,701	0,210	0,458	29,000	0,230	0,503
24	35	0,361	0,639	0,231	0,480	25,543	0,140	0,291
25	67	0,691	0,309	0,214	0,462	25,045	0,229	0,495
26	44	0,454	0,546	0,248	0,498	25,750	0,186	0,373
27	27	0,278	0,722	0,201	0,448	22,519	0,014	0,032
28	56	0,577	0,423	0,244	0,494	25,464	0,218	0,442
29	61	0,629	0,371	0,233	0,483	25,410	0,234	0,484
30	46	0,474	0,526	0,249	0,499	28,043	0,315	0,630
31	17	0,175	0,825	0,145	0,380	25,353	0,064	0,169
32	19	0,196	0,804	0,158	0,397	28,684	0,144	0,363
33	24	0,247	0,753	0,186	0,432	28,167	0,168	0,388
34	59	0,608	0,392	0,238	0,488	25,000	0,199	0,407
35	47	0,485	0,515	0,250	0,500	24,277	0,119	0,239
36	27	0,278	0,722	0,201	0,448	28,259	0,191	0,427

TABLE 6 Continued: Item-test Correlations Computed by the Item Analysis Programme (NP50) on the HL FCT Data

ITEM-TEST CORRELATIONS

ITEM	NJ	PJ	PW	SJ2	SJ	XBARJ	RXSJ	RX
37	33	0,340	0,660	0,224	0,474	25,879	0,144	0,304
38	37	0,381	0,619	0,236	0,486	26,649	0,194	0,400
39	35	0,361	0,639	0,231	0,480	26,057	0,160	0,333
40	55	0,567	0,433	0,246	0,495	21,873	-0,011	-0,023
41	46	0,474	0,526	0,249	0,499	26,239	0,220	0,440
42	28	0,289	0,711	0,205	0,453	27,036	0,159	0,352
43	4	0,041	0,959	0,040	0,199	21,750	-0,001	-0,007
44	20	0,206	0,794	0,164	0,405	27,450	0,123	0,305
45	4	0,041	0,959	0,040	0,199	25,500	0,016	0,079
46	13	0,134	0,866	0,116	0,341	27,154	0,076	0,222
47	47	0,485	0,515	0,250	0,500	25,468	0,183	0,367
48	42	0,433	0,567	0,246	0,495	25,048	0,144	0,290
49	8	0,082	0,918	0,076	0,275	25,125	0,028	0,102
50	13	0,134	0,866	0,116	0,341	27,231	0,077	0,226
51	16	0,165	0,835	0,138	0,371	27,688	0,103	0,277
52	5	0,052	0,948	0,049	0,221	27,000	0,028	0,128
53	20	0,206	0,794	0,164	0,405	26,000	0,090	0,223
54	16	0,165	0,835	0,138	0,371	24,313	0,041	0,111

TABLE 6 Continued: Item-test Correlations Computed by the Item Analysis Programme (NP50) on the HL FCT Data

3.3.4 MEANS AND STANDARD DEVIATIONS OF ITEM STATISTICS

NP50 computes the overall mean and standard deviation of the statistics provided for the individual items included in the test. Table 7 shows an extract of these statistics.

MEANS AND STANDARD DEVIATIONS OF ITEM STATISTICS			
	PJ	RXSJ	RX
MEAN	0,408	0,167	0,362
SD	0,202	0,092	0,185

TABLE 7: Means and Standard Deviations of Item Statistics of HL FCT Data Computed by NP50

On examining the figures in Table 7, it can be seen that the difficulty of a hypothetical average item is 0,408, i.e., 40,89 of the respondents would have answered such an item correctly. Since less than half of the respondents answered correctly, the testees found the test fairly difficult resulting in a positively skewed distribution. This was shown in Table 5.

Turning now to the statistic RXSJ or Gulliksen's index, it may be seen that the mean is 0,167 over all items. Gulliksen's index is an extremely useful criterion for deciding whether to retain or to drop items when refining a test. This index is often preferred to the straightforward item-test point biserial correlation (RX) since it takes into account the standard deviation of the item.

3.3.5 RELIABILITY COEFFICIENTS

The programme calculates four coefficients of reliability. Of these, the Kuder-Richardson 20 (K-R 20) coefficient is by far the most popular index of internal consistency. The less popular K-R 14 estimate of reliability assumes equal item inter-correlations (see Kuder and Richardson, 1937; Horst 1953b). The other two reliability indices provided, the Horst and Loevinger (see Horst 1953 a), are infrequently used.

Table 8 below is a display of the reliability coefficients supplied by the programme.

RELIABILITY COEFFICIENTS	
Kuder-Richardson 20	0,883
Kuder-Richardson 14	0,883
Loevinger	0,197
Horst 21	0,893

TABLE 8: Reliability Coefficients of the HL FCT Computed by NP50

The K-R 20 index indicates that the HL FCT has a reliability comfortably in excess of the "rule of thumb" lowest acceptable minimum of 0,75.

3.3.6 THE ITERATIVE FACILITY OF NP50

Ideally, the test constructor aims to produce a homogeneous set of items in order to create a unidimensional test. To achieve a test of such internal consistency, the item pool should be successively refined. In the case where the bulk of the items measure a single dimension, the test can be made increasingly unidimensional by successively dropping those items which do not meet certain criteria. The test and item statistics should then be recomputed on the reduced pool of items to evaluate whether the test has been improved. This process then continues, with weaker items being dropped from the test on each successive occasion until the test constructor is satisfied that an optimal subset of items in terms of internal consistency, distribution form and number has been selected from the original set of items.

NP50 can be used to achieve the above-mentioned aims. The programme can be used iteratively, dropping items which fall below a specified item-test correlation level. The programme user can choose such criteria as RX or RXSJ to use in item selection. He specifies too, the value of the critical index and the step size by which this index is increased on each iteration. The iteration procedure stops either when the maximum number of iterations specified by the user has been reached or when the reliability (K-R 20) has decreased on two successive iterations.

Tables 9 a - e show the seventh iteration performed on the test items. By this time the programme has dropped 18 of the 54 items. At each stage of the iteration procedure, revised test score statistics, distribution of test scores, item-test statistics, means and standard deviations of item statistics and reliability coefficients are computed.

N	MEAN	95% LIMITS OF MEAN	SD	95% LIMITS OF SD
97	17,711	16,078 - 19,348	8,105	7,103 - 9,439

TABLE 9a: Test Score Characteristics of the HL FCT computed by NP50 on the Seventh Iteration

DISTRIBUTION OF TEST SCORES		
0	1,933	X
1	4,867	XXXX
2	5,000	XXXX
3	6,933	XXXXXX
4	7,267	XXXXXX
5	5,200	XXXX
6	8,400	XXXXXXX
7	15,800	XXXXXXXXXXXXXXX
8	8,000	XXXXXXX
9	10,267	XXXXXXXXX
10	9,733	XXXXXXXXX
11	6,000	XXXXX
12	4,667	XXXX
13	2,467	XX
14	0,467	

Maximum Test Score = 34
Minimum Test Score = 1
Range = 33

TABLE 9b: Distribution of Scores on the HL FCT computed by NP50 on the Seventh Iteration

MEANS AND STANDARD DEVIATIONS OF ITEM STATISTICS			
	PJ	RXSJ	RX
MEAN	0,492	0,224	0,475
SD	0,164	0,058	0,121

TABLE 9d: Means and Standard Deviations of Item Statistics of HL FCT Data Computed by NP50 on the Seventh Iteration

ITEM-TEST CORRELATIONS

No. of Items in the Test Score = 36
(Items that are blank or marked with - are excluded from the test score)

ITEM	PJ	PW	XBARJ	RXSJ	RX
1	0,432	0,577	21,024	0,174	0,352
2	0,432	0,577	22,805	0,267	0,541
3	0,660	0,340	21,281	0,292	0,617
4	0,515	0,485	22,680	0,318	0,636
5	0,495	0,505	22,917	0,319	0,639
6	0,588	0,412	21,386	0,268	0,544
7	0,660	0,340	20,844	0,256	0,541
8	0,763	0,237	20,581	0,272	0,638
9	0,825	0,175	20,087	0,243	0,639
10	0,454	0,546	23,250	0,312	0,626
11	0,763	0,237	20,865	0,298	0,702
-12	0,392	0,608	19,132	0,069	0,141
13	0,392	0,608	20,684	0,144	0,296
14	0,536	0,464	21,731	0,267	0,536
15	0,773	0,227	19,213	0,144	0,344
-16	0,485	0,515	19,532	0,109	0,219
17	0,340	0,660	22,606	0,207	0,436
-18	0,299	0,701	16,138	-0,058	-0,127

TABLE 9c: Item-test Correlations Computed by the NP50 on the HL FCT Data on the Seventh Iteration

ITEM-TEST CORRELATIONS

ITEM	PJ	PW	XBARJ	RXSJ	RX
19	0,330	0,670	22,750	0,206	0,438
20	0,670	0,330	21,415	0,308	0,655
21	0,392	0,608	22,553	0,235	0,482
22	0,567	0,433	21,218	0,247	0,498
23	0,299	0,701	24,000	0,233	0,509
24	0,361	0,639	20,914	0,143	0,298
25	0,691	0,309	20,522	0,241	0,521
26	0,454	0,546	20,636	0,165	0,331
-27	0,278	0,722	17,296	-0,014	-0,032
28	0,577	0,423	20,768	0,219	0,443
29	0,629	0,371	20,852	0,245	0,507
30	0,474	0,526	22,848	0,302	0,605
-31	0,175	0,825	19,941	0,048	0,127
32	0,196	0,804	23,684	0,145	0,366
33	0,247	0,753	22,833	0,157	0,364
34	0,608	0,392	20,220	0,189	0,388
-35	0,485	0,515	19,468	0,106	0,211
36	0,278	0,722	23,370	0,195	0,436
37	0,340	0,660	21,485	0,159	0,336
38	0,381	0,619	21,541	0,181	0,373
39	0,361	0,639	21,514	0,170	0,354

TABLE 9c: Item-test Correlations Computed by the NP50 on the HL FCT Data on the Seventh Iteration

ITEM-TEST CORRELATIONS

ITEM	PJ	PW	XBARJ	RXSJ	RX
-40	0,567	0,433	17,418	-0,021	-0,042
41	0,474	0,526	21,522	0,224	0,449
42	0,289	0,711	21,857	0,148	0,328
-43	0,041	0,959	16,000	-0,009	-0,044
-44	0,206	0,794	21,950	0,108	0,268
-45	0,041	0,959	20,000	0,012	0,059
-46	0,134	0,866	21,231	0,058	0,172
47	0,485	0,515	20,511	0,168	0,337
-48	0,433	0,567	19,810	0,113	0,227
-49	0,082	0,918	20,125	0,025	0,090
-50	0,134	0,866	21,385	0,061	0,179
-51	0,165	0,835	21,688	0,081	0,219
-52	0,052	0,948	20,200	0,016	0,072
-53	0,206	0,794	20,700	0,076	0,189
-54	0,165	0,835	18,750	0,021	0,057

TABLE 9c: Item-test Correlations Computed by the NP50 on the HL FCT Data on the Seventh Iteration

RELIABILITY COEFFICIENTS	
Kuder-Richardson 20	0,901
Kuder-Richardson 14	0,901
Loevinger	0,291
Horst 21	0,912

TABLE 9e: Reliability Coefficients of the HL FCT Computed by NP50 on the Seventh Iteration

From Tables 9a,b,c,d and e it may be seen that the programme has dropped 18 of 54 items by the seventh iteration. It has recalculated all statistics based on the reduced item pool. The new statistics are much improved for the following reasons:

* The test mean is nearer the centre of the distribution and the standard deviation is satisfactory;
* The test score distribution is approaching the normal distribution and is no longer distinctly positively skewed;
* The maximum test score obtained is closer to the maximum possible score than was the case for the 54 item version;
* The average difficulty value of an item has increased from 0,408 to 0,492 indicating that about half of the respondents would respond correctly to the "hypothetical average item";
* The reliability of the test is extremely high indicating a test with high internal consistency.

Thus, by the process of iterative item analysis, the optimal subset of original items can be selected.

The item response evaluation and item analysis described above are only two of the many analysis which were carried out in the construction of the 24 item version HL FCT. There followed detailed analysis of the statistics obtained from all of the ten samples tested. This process finally lead to a test of 24 items which had highly acceptable characteristics for the population groups for which it is intended.

As was mentioned previously the HL FCT went through three major stages in its development. In this process the number of items was reduced from 54 to 36 and finally to 24. Table 10 summarises this development.

ANALYSIS NO.	SAMPLE TESTED	ANALYSIS
1	97 Black Construction Workers	Iterative Item Analysis
2	97 Black Construction Workers	Item Response Evaluation
3	87 Asian Insurance Workers	Iterative Item Analysis
4	87 Asian Insurance Workers	Item Response Evaluation
5	184 Black and Asian Workers (above samples combined)	Item Response Evaluation on: i) 54 items ii) 35 items iii) 38 items
6	184 Black and Asian Workers	Item Analysis on 36 Selected Items
7	451 Black Nurses at Baragwanath Hospital	Item Analysis
8	451 Black Nurses at Baragwanath Hospital	Item Response Evaluation
9	145 First-year Fort Hare Students	Item Analysis
10	145 First-year Fort Hare Students	Item Response Evaluation
11	93 Asian Sugar Workers	Item Analysis
12	165 Black Sugar Workers	Item Analysis
13	263 Black Male Applicants for Technical Training	Item Analysis
14	199 First-year Mabopani East Technikon Students	Basic Statistics (means, standard deviation, reliability, distribution form)
15	126 Black Work-seekers	Basic Statistics
16	127 Sowetan Pupils	Basic Statistics

TABLE 10: Analyses carried out on the data collected from 10 samples which lead to the final version HL FCT

4.0 EVALUATION AND VALIDATION OF THE HL FCT (24 ITEM VERSION)

The 24 item version HL FCT was administered to six samples. The first section of this chapter describes the basic statistics of the HL FCT on these samples. The second section presents detailed descriptions of four samples used for the validation of the test. Thereafter, the validation of the HL FCT is discussed for each of these samples. The final section compares the HL FCT and the Mental Alertness Test and argues for the inclusion of both tests in many prediction procedures.

4.1 MEANS, STANDARD DEVIATIONS AND OTHER BASIC STATISTICS OF THE HL FCT

The 24 item version of the HL FCT was administered to six samples (samples v to x listed on page 14). On the basis of the data collected from these samples, the test was critically evaluated. Special attention was paid to the test mean, variance, reliability and distribution form in each of the six samples.

Histograms of the distribution of scores for each of the samples tested are found in Appendix (i).

The sample size, mean, variance, standard deviation and coefficient of internal consistency (K-R 21) for the six samples are presented in Table 11.

SAMPLE	v ASIAN SUGAR WORKERS	vi BLACK SUGAR WORKERS	vii BLACK MALE APPLICANTS FOR TECHNICAL POSITIONS	viii FIRST YEAR MABOPANE EAST TECHNIKON STUDENTS	ix BLACK MALE WORK-SEEKERS AT O.V. ADMIN. BOARD	x SOWETAN MALE PUPILS
n	93	165	263	199	126	127
mean	15,04	13,85	12,65	14,83	10,27	16,91
variance	22,32	32,25	29,67	26,93	30,1	17,13
standard deviation	4,27	5,67	5,45	5,19	5,49	4,14
reliability K-R 21	0,781	0,784	0,833	0,824	0,84	0,74

TABLE 11: Sample size, mean, variance, standard deviation and reliability statistics for the HL FCT on each of the six samples tested.

Several observations based on these statistics follow:

Apart from the score distirbution of the Black work-seekers (sample ix) all distributions are similar in form. There appears to be a slight positive skewness in all samples except sample ix. Distributions of this form can be most useful in industry where it is required to select out those who would not succeed on the job. The similarity of the distributions suggests that the test may be used for Asian and Black race groups. Further testing may reveal the applicability of the test to other race groups. The relatively high frequency of very low scores in the distribution of the Black work-seekers suggests that there may be a number of respondents with less than the required minimum of ten years of schooling or that the greater proportion of older subjects in this sample was responsible for the low scores.

The mean score of 12,65 for the applicant group (sample vii) is in the middle of the distribution for a test consisting of 24 items. The relatively low mean of 10,27 for the Black work-seekers is a result of the large number of very low test scores. The mean scores for all the other groups are higher. For the matriculated Asian and Black sugar workers, the first-year Technikon students and the Sowetan matric students, the relatively high mean scores (15,04; 13,85; 14,83; 16,91) show that the HL FCT scores generally increase with increasing years of education. The high mean score for the Sowetan pupils is not unexpected since this was a fairly highly selected sample of pupils studying matric mathematics and science. When one considers the Black samples only, it is interesting to observe that the mean scores for the HL FCT are highest in the Technikon and Sowetan students. This may be because people in an educational contest are more accustomed to tests and examinations than industrial workers and therefore score better in a testing situation. Another factor favoring the students over the industrial workers is that they are younger. However, the HL FCT is still suitable for testing at the upper education range since only a small percentage of each of the sample scores above 20.

The coefficients of internal consistency (K-R 21) quoted above are considered satisfactory. The relatively lower coefficient of consistency for the Sowetan group (0,74) is the result of the highly homogeneous nature of the sample. One should bear in mind that this sample has the lowest variance of all (17,13). It should be remembered too that the K-R 21 coefficient is actually an underestimate of the K-R 20 coefficient of reliability.

4.2 DESCRIPTION OF THE SAMPLES USED FOR VALIDATION PURPOSES

For this section of the report it is necessary to give a detailed description of each of the samples which provided validation data for the HL FCT. Validation data was available for four of the six samples.

4.2.1 SAMPLES v AND vi

Two samples of apprentices in the mechanical trades of the sugar industry were tested on the HL FCT. All these subjects were matriculants who had passed matric mathematics and science.

Sample v consisted of 93 Asians with age range 16 - 26 years and average age = 19,9 years.

Sample vi consisted of 165 Blacks with age range 17 - 33 years and average age = 22,1 years.

The B/2/2 version of the Mental Alertness (MA), Mechanical Comprehension Test (A/3/1), Blox, Technical Reading Comprehension from the General Science Test (TRC) and Gottschaldt Figures Test (GFT) were administered to the Asian sample and to 72 of the Black sample. In addition, the matric mathematics and science marks were obtained to serve as additional criterion data for validation of the HL FCT.

4.2.2 SAMPLE vii

In 1980 a sample was collected of 263 Black males who applied for training as technicians for electronic and electromechanical equipment (adding machines, copiers, etc.). The age range was 17 - 29 years and education range 8 - 10 years.

These applicants were given a battery of tests comprising the HL FCT and other NIPR tests - the Mental Alertness Intermediate Level (IMA), A/3/1, Blox, TRC, as well as two spatial tests - the 'F' and the 'H' (see Taylor, 1980 for descriptions of the 'F' and 'H' tests). On the basis of these test results and interviews, a sample of 66 Blacks was selected. After one year's training, criterion data were collected in the form of end-of-year tests and examination results.

4.2.3 SAMPLE viii

In February 1982, 199 first year students of the Mabopani East Technikon were tested to assess the feasibility of using NIPR tests for selection of students for the Science Department of the Technikon.

Tests administered to this sample were the HL FCT, IMA, BLOX, TRC as well as two new experimental NIPR tests - the Estimation Test (ESTIM) and the Standard Level Arithmetic Reasoning Test (SL ART).

4.3 VALIDATION OF THE HL FCT

The valication of the HL FCT will be discussed separately for the Asian and Black sugar workers (samples v and vi), the Black male applicants for technical positions (sample vii), and the first year Mabopani East Technikon students (sample viii).

4.3.1 SAMPLES v AND vi

The correlations between the HL FCT and the mathematics and science criterion scores for the Asian and Black Sugar Workers are:

Sample / Criterion	ASIANS (n = 93)	BLACK (n = 72)
mathematics	0,29*	0,32*
science	0,08	0,40*

TABLE 12: HL FCT Correlations with Matric Mathematics and Science Scores for Asian Sugar Workers (n=93) and Black Sugar Workers (n=72)

* indicates correlations significantly different from 0 ($p < 0,05$).

The correlations between the HL FCT and the matric mathematics marks for both samples are significant.

The correlations between the science mark and the HL FCT is significant only for the Black sample. Upon examining Table 13 it can be seen that no test correlates significantly with the science mark. It is possible that something went amiss either in the collection of the data or in the science examination itself.

The complete intercorrelation matrix for the Asian Sugar Workers is set out in Table 13.

	MATHS	SCIENCE	MA	HL FCT	A/3/1	BLOX	TRC	GFT
MATHS								
SCIENCE	0,58 *							
MA	0,31 *	0,15						
HL FCT	0,29 *	0,08	0,61 *					
A/3/1	0,16	0,18	0,42 *	0,38 *				
BLOX	0,16	0,16	0,41 *	0,55 *	0,29 *			
TRC	0,22 *	0,12	0,59 *	0,28 *	0,20	0,22 *		
GFT	0,12	0,07	0,47 *	0,49 *	0,36 *	0,37 *	0,34 *	

TABLE 13: Intercorrelation Matrix for Asian Sugar Workers (n = 93)

* indicates correlations significantly different from 0 ($p \leqslant 0{,}05$).

The complete intercorrelation matrix for 72 of the Black Sugar Workers is displayed in Table 14.

	MATHS	SCIENCE	MA	HL FCT	A/3/1	BLOX	TRC	GFT
MATHS								
SCIENCE	0,85 *							
MA	0,40 *	0,45 *						
HL FCT	0,32 *	0,40 *	0,59 *					
A/3/1	0,26 *	0,39 *	0,53 *	0,31 *				
BLOX	0,04	0,11	0,24 *	0,49 *	0,25 *			
TRC	0,29 *	0,35 *	0,47 *	0,38 *	0,28 *	0,08		
GFT	0,26 *	0,40 *	0,19	0,15	0,27 *	0,38 *	0,25 *	

TABLE 14: Intercorrelation Matrix for Black Sugar Workers (n = 72)

* indicates correlations significantly different from 0 ($p \leqslant 0,05$)

As expected, the HL FCT correlated significantly with the MA (0,61 and 0,59 for the Asian and Black groups respectively) since the MA is a test of general mental ability. The tests differ however in that the HL FCT is a non-verbal test and the MA has a high verbal content.

The significant correlations between the HL FCT and the A/3/1 for both samples (r = 0,33 and 0,31 respectively) and between the HL FCT and the BLOX for both samples (r = 0,55 and 0,49 respectively) reflect the spatial and reasoning components common to the HL FCT, A/3/1 and the BLOX.

It is not surprising that there is a significant (although moderate) correlation between the HL FCT and the TRC for the two samples (r = 0,28 and 0,38 respectively) since the task in the HL FCT involves reasoning and the TRC also has a reasoning component.

Correlations between the HL FCT and the GFT were found to be significant only in the case of the Asian sample (r = 0,49) but not in the case of the Black sample (r = 0,15). Since the GFT can be thought of as a test of perceptual analysis, it appears that the Asian group may be using a similar analytic-type strategy in solving the problems of the GFT and HL FCT. Blacks, on the other hand, are probably using a more holistic, perceptual-type approach in solving the items of the GFT. Since this approach is not possible in the solution of most HL FCT items, the correlation between HL FCT and GFT is low.

4.3.2 SAMPLE vii

The intercorrelation matrix of the test battery scores of the entire group of Black male applicants (n = 263) is given in Table 15.

	IMA	HL FCT	A/3/1	BLOX	TRC	SL ART	F
IMA							
HL FCT	0,60 *						
A/3/1	0,41 *	0,35 *					
BLOX	0,29 *	0,36 *	0,20 *				
TRC	0,42 *	0,29 *	0,28 *	0,14 *			
SL ART	0,37 *	0,36 *	0,14 *	0,13 *	0,25 *		
F	0,27 *	0,25 *	0,12	0,23 *	0,06	0,22 *	
H	0,25 *	0,24 *	0,16 *	0,34 *	0,08	0,16 *	0,79 *

TABLE 15: Intercorrelation Matrix for Black Male Sample (n = 263)

* indicates correlations significantly different from 0 ($p \leqslant 0,05$).

	IMA	HL FCT	A/3/1	BLOX	TRC	SL ART	F	H	ELECTRONICS TEST	APPLIED MECHANICS TEST	TYPEWRITING TEST	ADDING MACHINE TEST
ELECTRONICS TEST	0,49*	0,54*	0,05	0,26*	0,18	0,11	0,01	0,08				
APPLIED MECHANICS TEST	0,32*	0,43*	0,26*	0,18	0,34*	0,11	-0,02	0,04	0,62*			
TYPEWRITING TEST	0,24*	0,29*	0,09	0,26*	0,09	0,08	-0,03	0,16	0,48*	0,42*		
ADDING MACHINE TEST	0,29*	0,30*	0,20	0,28*	0,26*	-0,13	-0,18	0,05	0,63*	0,48*	0,44*	
SELF STUDY	0,50*	0,51*	0,09	-0,31*	0,00	0,18	-0,17	0,06	0,42*	0,25*	0,30	0,62*

TABLE 16: Intercorrelation Matrix for 66 selected Black Male Technicians

From Table 15 it can be seen that the HL FCT correlates significantly with the MA, A/3/1, BLOX and TRC. These correlations are similar to those obtained for the Asian and Black Sugar workers (see section 4.3.1).

The significant correlation between the HL FCT and the SL ART (r = 0,36) is expected since both tests require a reasoning-type approach in their solution.

Finally, the moderate but significant correlations between the HL FCT and the two spatial tests, the F (r = 0,25) and the H (r = 0,24) show that there is a spatial element shared by these tests.

After selection, the sample size decreased to 66.

Intercorrelations between selected criterion scores and the test battery scores are shown in Table 16.

From the previous matrix, it can be seen that the HL FCT correlates substantially with all the criterion scores listed in Table 16 for the selected group of 66 trained male technicians. These correlations are particularly remarkable considering the highly selected nature of the sample.

In all cases, the HL FCT correlates more highly with the criterion scores (ELECTRONICS, APPLIED MECHANICS, TYPEWRITING, ADDING MACHINE, ELECTRONICS SELF STUDY) than does any other test in the battery (but not always significantly more highly).

4.3.3 SAMPLE viii

The intercorrelation matrix obtained on the 199 Mabopani East Technikon first year students is presented in Table 17.

	IMA	HL FCT	BLOX	TRC	SL ART	ESTIM
IMA						
HL FCT	0,48 *					
BLOX	0,38 *	0,35 *				
TRC	0,26 *	0,17 *	0,04			
SL ART	0,46 *	0,34 *	0,15 *	0,22 *		
EST	0,28 *	0,26 *	0,07 *	0,16 *	0,24 *	

TABLE 17: Intercorrelation matrix for 199 first-year Technikon students

As expected, the HL FCT correlates significantly with the IMA, BLOX, TRC as well as with the two new NIPR experimental tests, SL ART and ESTIM, which both require a reasoning-type approach in solving the items.

4.4 CONCLUSIONS

For the samples considered above, both the MA/IMA and the HL FCT correlate substantially with the criterion data. The HL FCT appears to perform better than the IMA as a predictor in the case of the selected group of Black male technicians. The two tests are by no means interchangeable since they are only moderately correlated (correlations vary between 0,48 for sample viii and 0,61 for sample v). It would appear that some of the predictive power of the MA might come from its verbal content whereas the ability of the HL FCT to predict criteria is probably based on the non-verbal conceptual demands which it places on the testee. It would therefore seem to be of value to employ both tests in many selection procedures.

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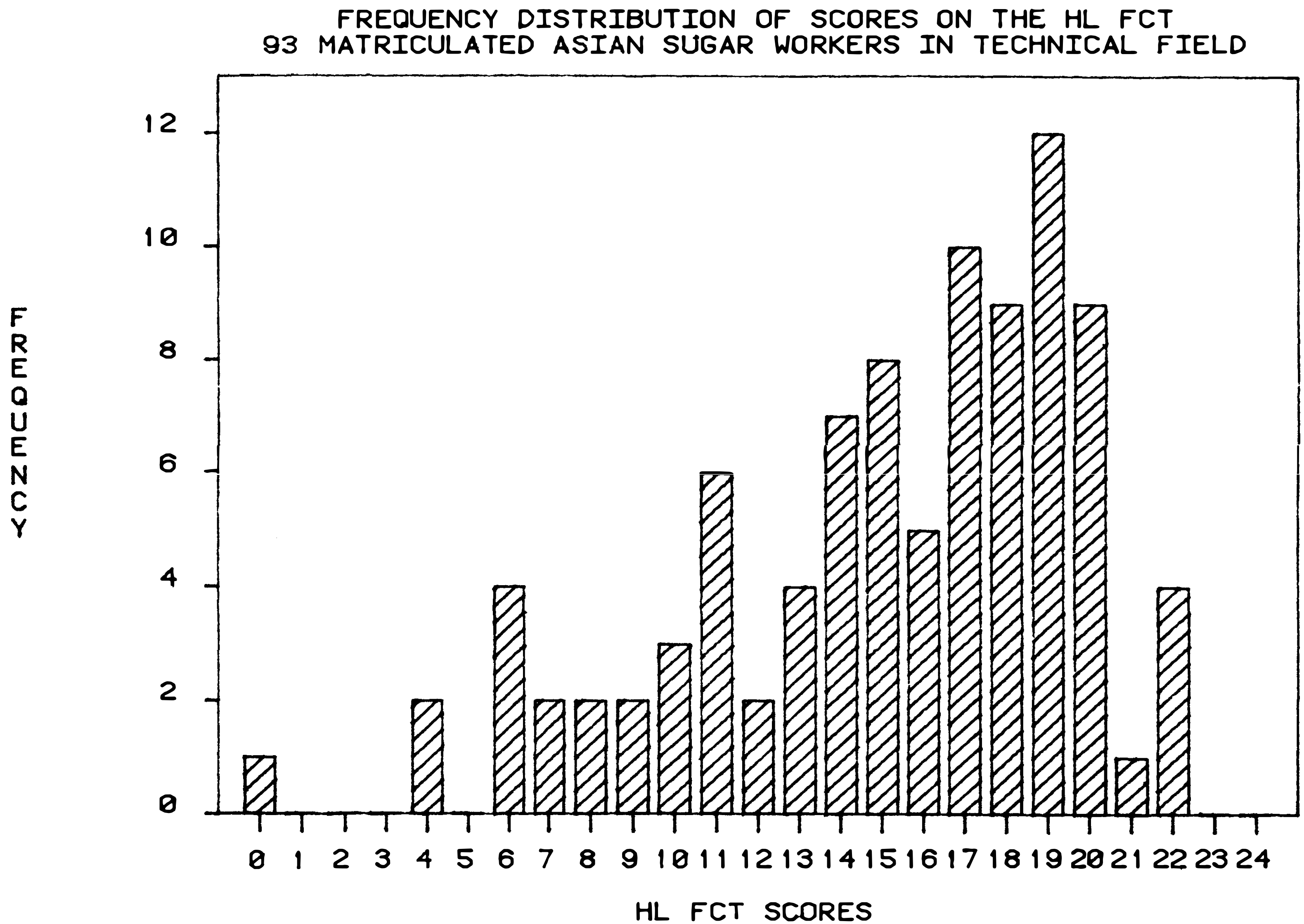
A P P E N D I X


FREQUENCY DISTRIBUTION OF SCORES ON THE HL FCT
93 MATRICULATED ASIAN SUGAR WORKERS IN TECHNICAL FIELD
FREQUENCY
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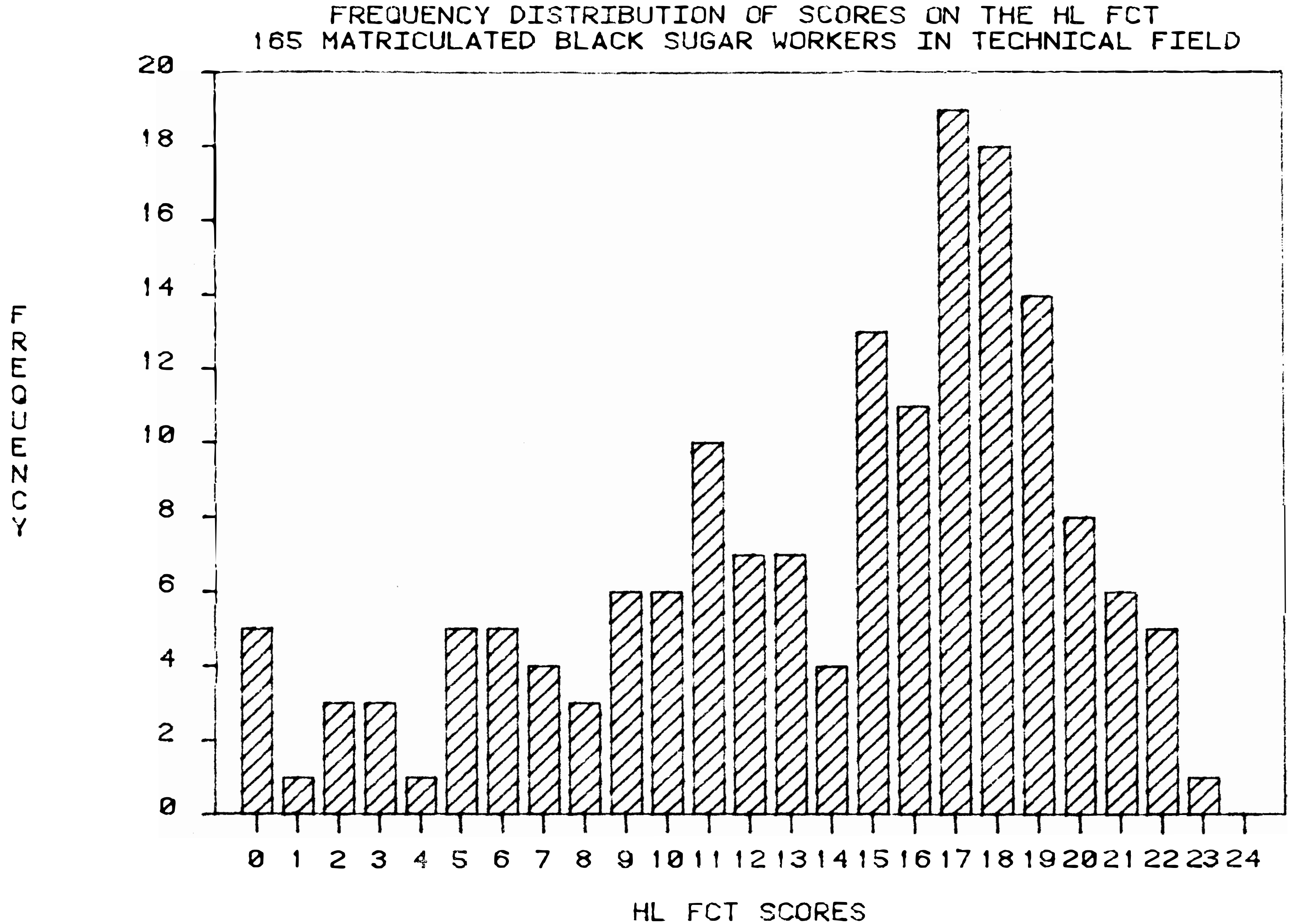
HL FCT SCORES

Figure 3


FREQUENCY DISTRIBUTION OF SCORES ON THE HL FCT
165 MATRICULATED BLACK SUGAR WORKERS IN TECHNICAL FIELD
FREQUENCY
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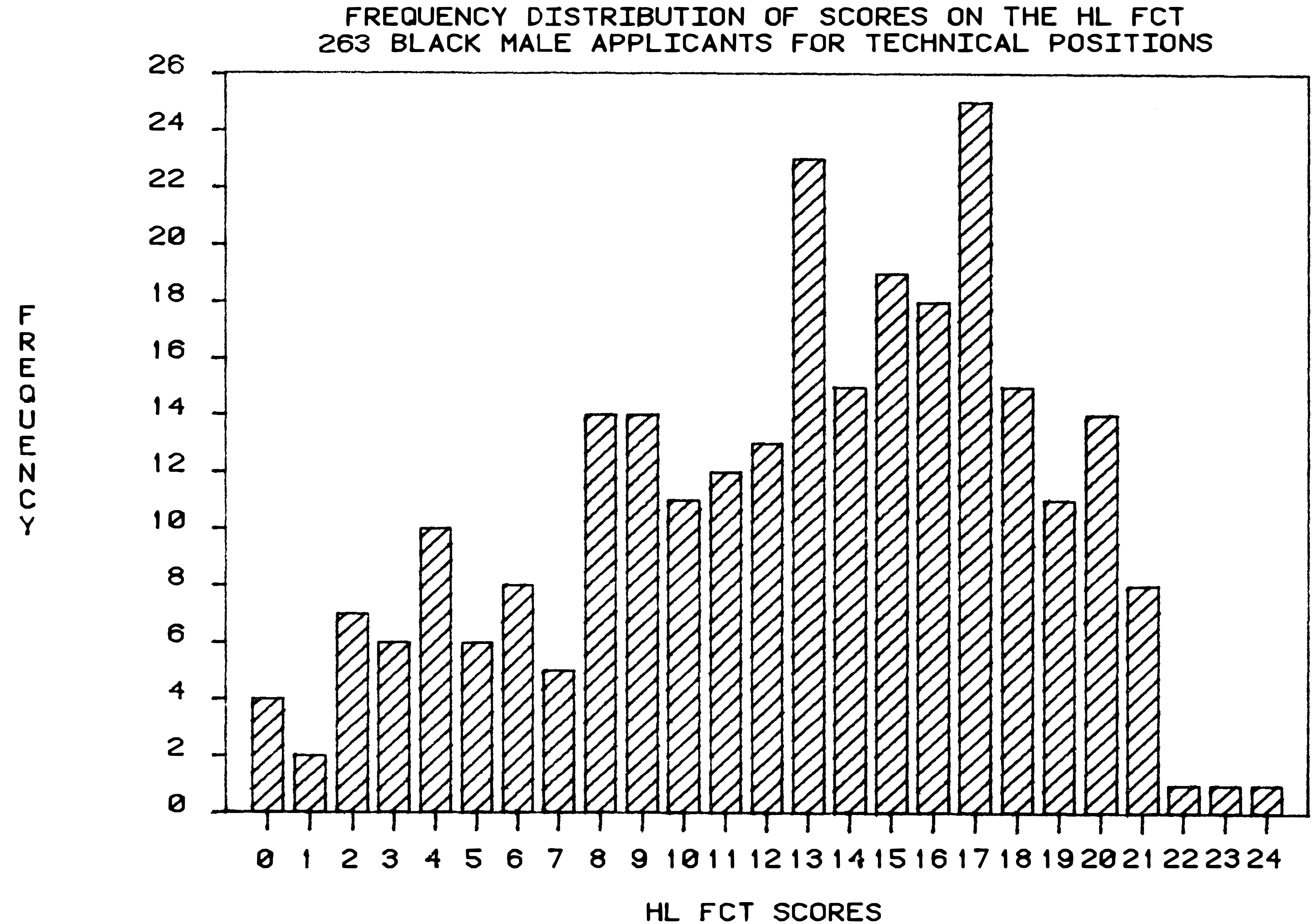
HL FCT SCORES

Figure 4


FREQUENCY DISTRIBUTION OF SCORES ON THE HL FCT
263 BLACK MALE APPLICANTS FOR TECHNICAL POSITIONS
FREQUENCY
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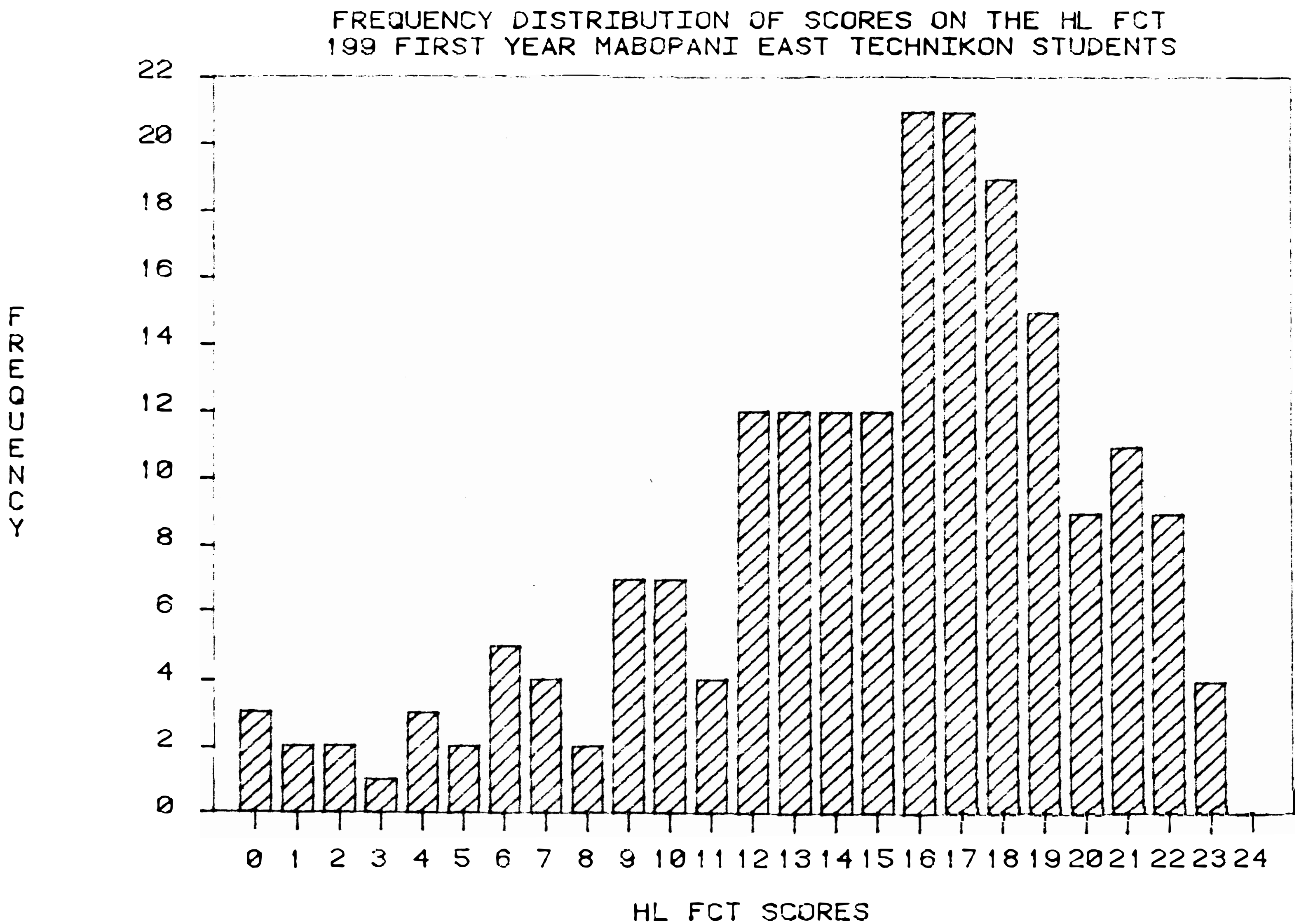
HL FCT SCORES

Figure 5


FREQUENCY DISTRIBUTION OF SCORES ON THE HL FCT
199 FIRST YEAR MABOPANI EAST TECHNIKON STUDENTS
FREQUENCY
HL FCT SCORES
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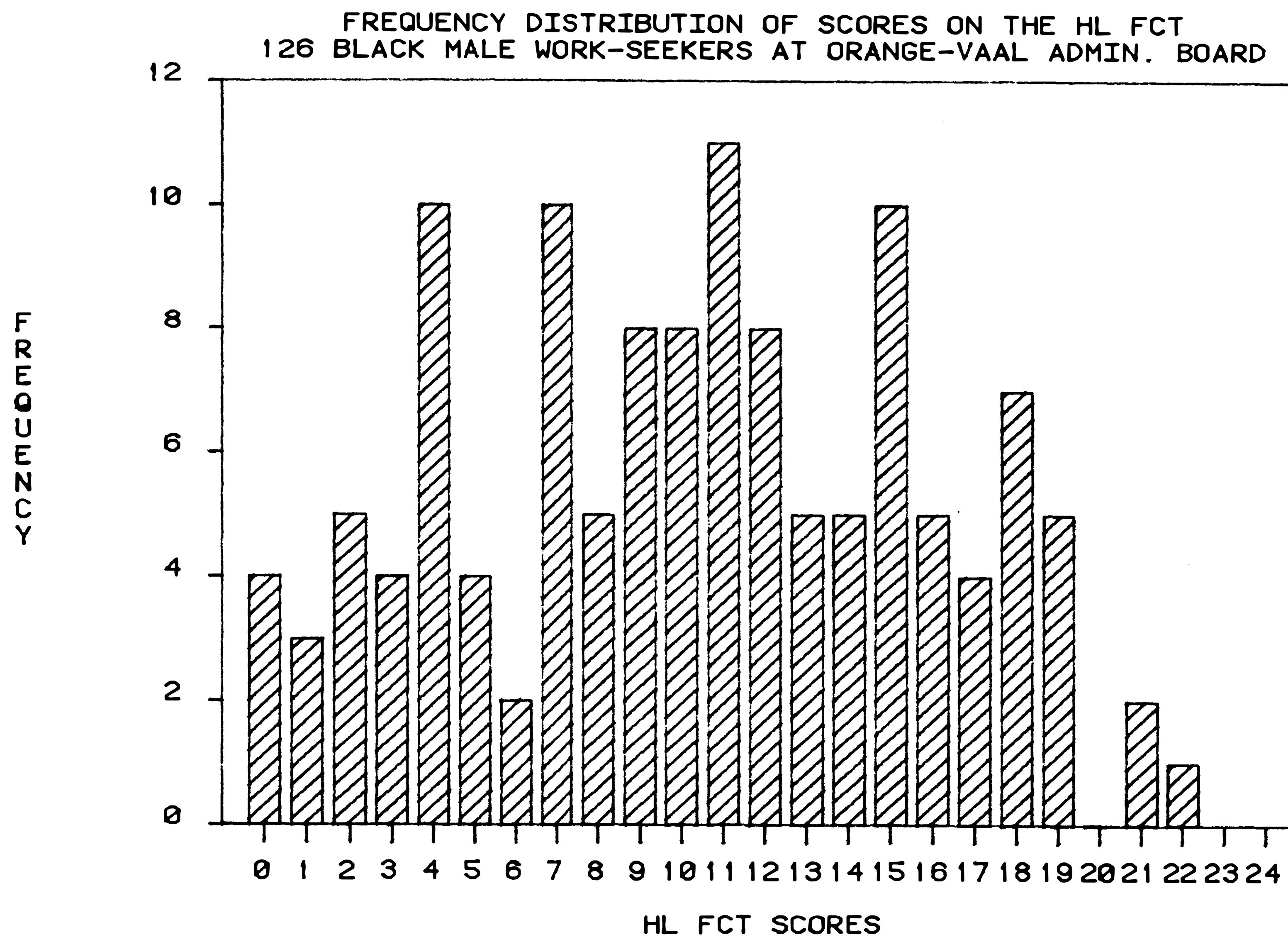
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Figure 6


FREQUENCY DISTRIBUTION OF SCORES ON THE HL FCT
126 BLACK MALE WORK-SEEKERS AT ORANGE-VAAL ADMIN. BOARD
FREQUENCY
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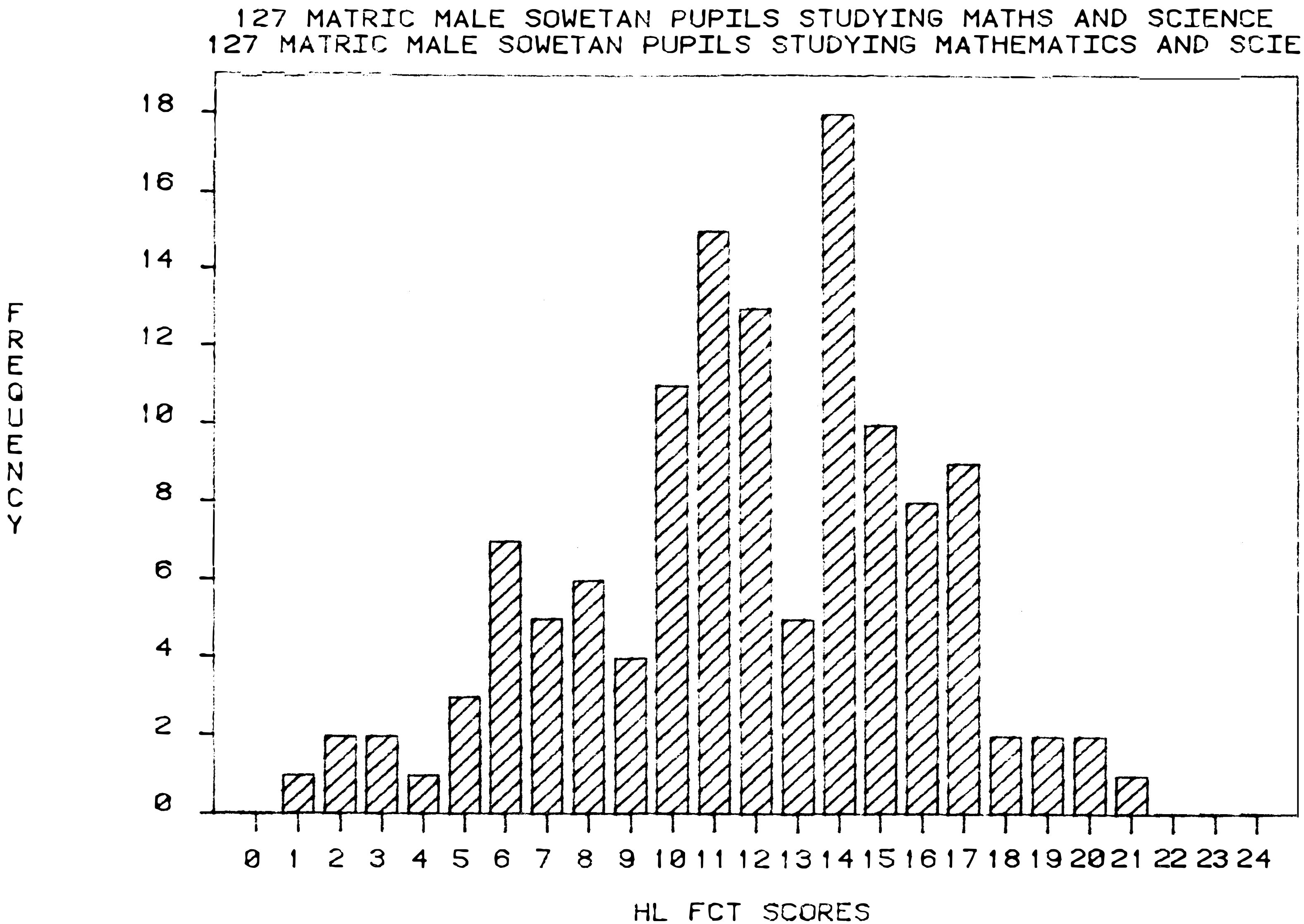
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
HL FCT SCORES

Figure 7


127 MATRIC MALE SOWETAN PUPILS STUDYING MATHS AND SCIENCE
127 MATRIC MALE SOWETAN PUPILS STUDYING MATHEMATICS AND SCIE
FREQUENCY
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HL FCT SCORES

Figure 8