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Development and validation of three tests of arithmetic ability

Marion E. Halstead

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Development and validation of three tests of arithmetic ability

Arithmetic Reasoning Test — High Level
Arithmetic Reasoning Test — Standard Level
Estimation Test — High Level

Marion E. Halstead

Pretoria
Human Sciences Research Council
1985

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OPSOMMING

Konvensionele numeriese toetse neig om die vermoë om roetine-berekeninge uit te voer te meet. Hierdie vermoë het met die aanbreek van die sakrekenaar-tydvak baie minder belangrik geword. Van meer belang is 'n begrip van die basiese reëls van rekenkunde, 'n vermoë om dié reëls toepaslik aan te wend en om te besluit of antwoorde wat op 'n sakrekenaar verkry is redelik is. Hierdie oorwegings is in gedagte gehou in die ontwikkeling van drie nuwe toetse van numeriese vermoë. Hierdie verslag beskryf die ontwikkeling en validering van die drie toetse.

SUMMARY

Conventional numerical tests tend to measure the ability to perform routine calculations. With the advent of the calculator era this ability has become far less important. More important is an understanding of the fundamental rules of arithmetic, the ability to apply the rules appropriately and to judge whether the answer obtained on a calculator is reasonable. Bearing these considerations in mind, three new tests of numerical ability were developed. This report describes the development and validation of the three tests.

1. INTRODUCTION

Conventional tests of numerical ability tend to reflect the school syllabus. The task in such tests may be to compute the correct answer to a complex numerical expression which incorporates many of the rules of arithmetic. In other conventional numerical tests a numerical problem is presented with a few relevant facts from which the subject must determine the method of approach and perform the necessary calculations. The Computation tests to be found in the Intermediate Battery (B77) and Normal Battery (A76) are examples of the former and the Arithmetic Problems Test to be found in the Intermediate Battery is an example of the latter.

With the advent of the calculator era, however, the ability to perform routine calculations has become far less important. Instead, the ability to estimate the answer to a problem is required, so that one can judge whether the answer obtained on a calculator is within reasonable limits. Furthermore, in real life situations problems are not presented with all the relevant facts. Rather, the relevant information must be teased out of a welter of extraneous facts and figures.

Bearing these considerations in mind, the Test Construction Division of the National Institute for Personnel Research (NIPR) embarked on a project to develop new tests of numerical ability. Three tests were conceptualized, each measuring a different aspect of numerical ability. These tests were the Arithmetic Reasoning Test (developed by T R Taylor), the Estimation Test (developed by N Tredoux and C S Chemel) and the Embedded Problems Test (developed by M E Halstead).

The Arithmetic Reasoning Test (ART) measures understanding of the fundamental rules of arithmetic and the application of these rules in logical strategies in order to solve problems of a purely numerical nature. Each item involves several logical and numerical steps. They are presented in a novel format to prevent the use of rote arithmetic procedures. Furthermore the items are cumbersome to solve algebraically, so that testees with algebraic experience have no advantage over those with little algebraic experience. The items are equations in which single digits have been replaced by symbols. These symbols are

□ which always represents any positive single digit

[which always represents half the value of □

⊡ which always represents one more than □

The subject's task is to work out the value of □ for each equation. In some cases, an operator has been omitted and replaced by the symbol ^. Taylor (1982, p28) provides an example of an item and the set of logical steps to solve the item.

□ 4^ ⊡ = $9\frac{1}{4}$

The following steps are required to solve this item.

(i) As the number on the right-hand side of the equation is a fraction, the operator must be ÷ (the only operators permitted are +,-,x,÷).

(ii) Hence $\frac{□4}{⊡} = \frac{37}{4}$

(iii) Try equating numerators and denominators. But the units digits in the numerators are not the same.

(iv) Since 37 is prime, the numerator on the left must be a multiple of 37. The obvious candidate is 2; 37 doubled will produce the digit 4 in the units column and this tallies with the 4 on the left-hand side numerator.

(v) Double 37 to produce 74. This gives a value of 7 for □

(vi) Check the whole equation, substituting 7+1=8 for ☐

$\frac{74}{8} = 9\frac{1}{4}$

The equation balances, the solution has been found.

Two versions of the Arithmetic Reasoning Test were developed that differ in difficulty level. These versions are known as the Arithmetic Reasoning Test - Standard Level (ART-SL) and the Arithmetic Reasoning Test - High Level (ART-HL). The ART-SL is most suitable for people with 10 to 12 years formal schooling while the ART-HL is most suitable for people with 12 years or more formal schooling.

The second test of numerical ability, the Estimation Test-High Level (ET-HL) measures the ability to make quick estimations of arithmetic expressions through the use of rounding and short-cut strategies.

An example of an item is provided in the instructions to the test.

41 x 24	a)	814,0
	b)	984,0
	c)	1154
	d)	1194
	e)	834

To do this item one should reason as follows :

> "41 is close to 40, and 24 is close to 25; 40 times 25 is a thousand; therefore the answer must be about a thousand. It cannot be far over a thousand, because 24 is less than 25. The correct answer must therefore be 'b'."

The necessity for using "intelligent" and flexible strategies in order to solve the problems in the quickest way indicates the participation of a general intellectual ability component in the test. The items involve the arithmetic operations of addition, subtraction, multiplication, division, square roots and squares. Items involving whole numbers, fractions and decimal numbers are included in the text.

Since two levels of the test are envisaged, the version under discussion will be known as the Estimation Test-High Level (ET-HL). The Estimation Test-High Level is appropriate for people with more than 10 years formal schooling.

The Embedded Problems Test (EPT) measures the ability to identify the procedure and information required to solve a verbally presented problem, extract the information from related but irrelevant material and calculate the answer. Subjects are presented with paragraphs of information describing a situation and have to answer four or five questions about each paragraph. Skills of numerical understanding and computation, as well as verbal skills are required for effective performance on the test. Although not factorially pure, it imposes demands of a nature similar to those imposed in many quantitatively orientated jobs and curricula. This test will be suitable for people with not less than twelve years education. As it is still in its experimental form its validation is not discussed per se in this report. It does, however, feature as an included test in validation exercises on the ART and ET-HL.

2. DEVELOPMENT OF THE ARITHMETIC REASONING TESTS AND ESTIMATION TEST

The data from two initial applications of the ART-HL (36-item version), one to a large group of White Technikon students and one to a group of trainee computer programmers, were analysed using the Item Response Evaluation program (IRE). The results for the Technikon group (n=151) indicated that the internal consistency of the test was high (Kuder-Richardson formula 20 = 0,86 when no response is taken as wrong and Kuder-Richardson formula 20 = 0,93 when no response is taken as missing information). Each item was evaluated in terms of its correlation with the test total, the proportion of endorsements of each response alternative and for difficulty level.

The results indicated that, with very few exceptions, the items performed well in terms of these psychometric properties. Data from the application of the test to trainee computer programmers yielded similar results. Since very few items could be rejected on the basis of being poor items, difficulty level of the item became the critical factor in deciding whether to reject or keep an item in the test. In this way the test was shortened to twenty four items. To shorten the ART-HL further would have reduced the internal consistency of the test.

The ART-SL (36 item version) was initially applied to 136 Black students undergoing a year of pre-technikon training. The mean of the test for this group was 19,3, standard deviation was 9,27 and Kuder-Richardson formula 20 was 0,939. A 19-item version of the ART-SL was applied to 92 Black Matriculants. Although this was a short version of the test the Kuder-Richardson formula 20 was 0,892, the mean was 9,28 and standard deviation was 5,28. Both sets of data were item analysed. As with the ART-HL, the test and item statistics proved satisfactory from the start. Items were rejected on the basis of their difficulty level. The final result was a 30-item test. Part of the success of the ART (SL and HL) in terms of its psychometric properties lies in the fact that there are nine alternative responses to every item. This reduces the undesirable effects of guessing.

The ART-HL and the ART-SL differ in format in that the former is subdivided into three sections with a 13 minute time limit for each section while in the latter the items are not subdivided and there is only one overall time limit. In analysing data on the ART-HL it became apparent that the strategy used by some subjects was one of trying a likely number, and if that did not work, trying another number. Since the subject knows whether his answer is incorrect and the range of possible answers lies between one and nine, he may keep on trying until he achieves the correct answer. This strategy might have been used more frequently in the high level version of the test because of the greater complexity of the items. In order to reduce this problem the ART-HL was divided into three sections with a time constraint of thirteen minutes per section. After thirteen minutes on a section the subject is told to move on to the next section. This has the effect of encouraging the subject to attempt to solve the item by using quick arithmetic strategies and if these do not work, to move on to the next item.

The Estimation Test-HL initially had forty items. Items were constructed to incorporate a sampling of all types of numerical operations eg. addition, subtraction, multiplication, division, squares, square roots and quadratic equations. The test is available in both a paper-and-pencil format and on the NIPR's PLATO computerized testing system. Other than mode of presentation, the major difference between ET-HL and ET-HL (computerized) is that in the paper-and-pencil version the whole test is timed while in the computerized version each item is timed and the time limits per item are set so as to prevent "accurate" or "complete" calculation of the answers.

The paper-and-pencil version was applied to accountancy honours students at an Afrikaans university while the computerized version was applied to clerical staff at a semi-government organisation. Both these studies resulted in the elimination of the harder items involving quadratic equations. On the basis of both these studies 26 items were selected for the final version of the test. In the computerized test nineteen items were selected that were particularly appropriate for clerical staff. The test is presented in its 26-item format but only nineteen items are scored. The seven unscored items contain squares and square roots which are not generally used by clerical staff.

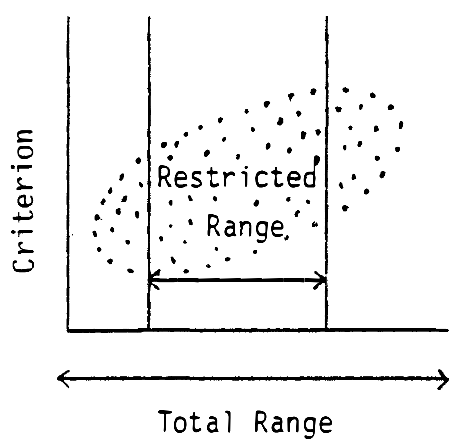
3. BACKGROUND INFORMATION

Before examining the validation studies consideration must be paid to several points.

The size of a correlation coefficient depends partially upon the heterogeneity of the population from which the data is obtained. In a homogeneous population the range of ability can be small. The narrower the range the smaller the correlation coefficient tends to be. Figure 1 illustrates the point made.

FIGURE 1

EFFECT OF RESTRICTION OF RANGE ON CORRELATION COEFFICIENTS



The effects of restriction of range may be seen in both internal consistency figures (generally Kuder-Richardson formula 20 or 21 in this report) and in the validity coefficients.

Ideally in validation studies one would like to apply a battery of tests, ignore the results and collect the validation data. This seldom happens in practice. Sometimes selection is based on the predictor variable. Lord and Novick (1968, p.141) present hypothetical data showing how the variance in the selection variable reduces as the population group is increasingly selected. A few examples from this data are presented as an example. These figures are based on scores that are normally distributed with unit variance.

TABLE 1

VARIANCE IN THE SELECTED GROUP WHEN THE TOP P PERCENT ARE SELECTED FROM A STANDARD NORMAL POPULATION

Percent Selected	100	80	60	50	40	20	10
Standard deviation in selected group	1	0,76	0,65	0,60	0,56	0,47	0,41

To the extent that the selection variable and the criterion correlate, restriction of range will occur in both variables resulting in an underestimate of the test's validity. Lord and Novick (1968, p.141) refer to selection on a specific variable as explicit selection. They refer to consequent effects on other variables which correlate with the variable on which selection was done as incidental selection.

Explicit and incidental selection affect the relative size of the validity coefficients so that a test that is highly valid for the total group may appear invalid on a selected sample. Lord and Novick (1968, p.143) offer a technique whereby the "true" validity coefficient can be estimated by eliminating the effects of selection. Two assumptions must be satisfied before the technique can be applied. These assumptions are firstly that, if X is the explicit selection variable and Z the criterion variable, the regression of Z on X is the same in the selected and unselected groups. The second assumption is that the variance of Z is the same for both groups.

So far the discussion has centered around the situation where selection is based on the predictor variable. More often in validation exercises the unselected group is given a battery of tests which incorporate for example a standard test on which predictions are usually made and an experimental test which is being considered as a replacement predictor. Where explicit selection is on variable X incidental selection will occur on both Z (the criterion variable) and Y (the proposed predictor). A technique to determine the correlation between Y and Z in the unselected group is discussed in Lord and Norvick (1968, P.144). The assumptions are similar to those in the case above viz. the true regressions of Y on X and Z on X are linear and the variance of Y given X, the variance of Z given X and the covariance of Z and Y given X, do not depend upon X.

The technique has been generalized to the case where several variables are subject to explicit selection and other variables correlated with these are subject to incidental selection. For a more detailed consideration of these concepts the reader is referred to the chapter on Measurement Precision, Estimation and Prediction by Lord and Novick (1968).

Most of the validation studies in this report are based on a model of convergent and discriminant validity. Both types of validity are used to establish the construct validity of the tests. Construct validity is the extent to which a test measures what it purports to measure. Convergent validity is demonstrated by high correlations with other instruments that are designed to measure in the same content domain. Discriminant validity occurs when the test correlates at a lower level with instruments which are designed to measure different content domains. In the validation of the ART (SL and HL) and ET-HL an attempt was made to incorporate a wide variety of tests so that the construct validity of these tests could be demonstrated.

Validation studies were conducted on the ART (HL and SL) and the ET-HL throughout their development. Thus some of the

studies discussed are based on earlier versions of the tests. These results are included since it is felt that the content domain of the tests was not substantially altered. Testing on the early versions would be expected to yield inferior results (from a psychometric and validity point of view) than those obtained from the refined versions of the tests. Hence they would tend to underestimate the performance of the tests.

A number of tests were included repeatedly in test batteries in which the ART (SL and HL) and the ET-HL were used. These will be described in the next section. Thereafter, studies in which the ART-HL was used will be discussed and then studies in which the ART-SL was employed. Since the ET-HL was generally applied in conjunction with either ART-HL or ART-SL it will be discussed together with these tests. Finally studies in which the ET-HL was applied without the ART-HL or ART-SL will be presented.

4. THE PREDICTORS

Only the tests produced by the National Institute for Personnel Research will be described in this section. In some of the studies other predictors such as in-house tests were used. These will be described together with the relevant research. The tests that were applied fall into five categories: cognitive (Mental Alertness Test, Deductive Reasoning Test, Figure Classification Test, Conceptual Reasoning Test and Pattern Relations), number (Arithmetic Problems, Computation), verbal (Reading Comprehension, Vocabulary, Words-in-Context), spatial (Blox, Gottschaldt Figures Test, Rotate and Flip Test, F-test and H-test) and scientific Knowledge and comprehension (Mechanical Comprehension Test, General Science Test).

4.1 Mental Alertness Tests

The Mental Alertness Tests are measures of general intellectual functioning. The questions are presented in a verbal format. Reasoning tasks in the form of codes (number and letter), similarities, analogies and number and letter series are presented. Two levels of this test were used in the validation studies. The high level Mental Alertness (MA-HL) contains 42 items and is suitable for subjects with at least matric. The intermediate Mental Alertness (MA-I) contains 30 items and is appropriate for people with ten to twelve years of education.

4.2 Deductive Reasoning Test

The Deductive Reasoning Test measures the ability "to make valid inferences from given information" (Verster, 1973, p.2). The subject is presented with syllogisms containing three classes of semantic content, factual, contra-factual and nonsense, from which he must deduce the correct conclusion. The high level version (DRT-HL) is not suitable for people with less than twelve years education and has been successfully applied to graduates. These are 36 items in the test. The 25 item intermediate version (DRT-I) is appropriate for people with less than twelve years of schooling.

4.3 Figure Classification Test

The Figure Classification Test (FCT-HL) is a measure of "general intellectual ability uncontaminated by verbal skills" (Werbeloff and Taylor, 1982, p.7). The subjects' task is to classify six diagrams into two groups of three by identifying relevant concepts from irrelevant distractors. There are 24 items. The test is designed for use with people who have between ten to twelve years of schooling.

4.4 Conceptual Reasoning Test

The Conceptual Reasoning Test (CRT) is a non-verbal test of intellectual functioning. The test is similar to the Raven's Progressive Matrices in that the subject's task is to complete a display with a missing component. However, each item of the CRT has a unique format, unlike the Raven's which includes only 3x3 matrices. The subject has to determine how the components are related in order to solve each item. The relationships within each item may be based on analogies, odd-man-out, series etc. The initial 52 item test was later broken down into two versions in which items were modified and new items inserted.

The CRT-SL is appropriate for matriculants while the high level version (CRT-HL) is appropriate for bursary applicants and graduates.

4.5 Pattern Relations Test

The Pattern Relations Test is a non-verbal test of intellectual functioning. It is based on the Raven's Progressive Matrices. The subject is presented with a 3x3 matrix from which one block is missing. His task is to work out which of six possible answers is correct. This test is most suitable for university graduates.

4.6 Arithmetic Problems Test

The Arithmetic Problems Test measures the ability to formulate and solve numerical problems. Only the relevant facts are given in each item. The high level version of the Arithmetic Problems Test (AP-HL) and the intermediate level version (AP-IL) form part of the High Level Battery and Intermediate Battery respectively.

4.7 Computation Test

The Computation Test (CT) requires the subject to calculate the value of relatively complex numerical expressions using strategies taught at school. The expressions are presented in a way which allows the subject to proceed directly with the task: no structuring or formulation of the problem is required. The test is suitable for people with ten to twelve years of schooling.

4.8 Reading Comprehension Test

The Reading Comprehension Test is a 20 item test of the ability to read and understand the contents of a paragraph. Although available in several different versions, only that from the High Level Battery was used (RC-HL). Thus the test used was appropriate for people with not less than twelve years schooling.

4.9 Vocabulary Test

The Vocabulary Test from the High Level Battery (Voc-HL) was used to assess the subjects' general vocabulary level. The test is most appropriate for people with not less than twelve years of schooling.

4.10 Words-in-Context Test

The Words-in-Context Test (WICT-HL) is an experimental vocabulary test. It differs from Voc-HL in that the word is embedded within the context of a sentence, rather than being presented in isolation. The test is available in English and Afrikaans, and at two levels of difficulty. The high level versions are suitable as measures of vocabulary ability in the home language of the subject while the standard level versions may be used to assess the subject's ability in the second language.

4.11 Blox Test

The Blox Test is a measure of spatial relations and orientation, i.e. the ability to mentally rotate an entire configuration with respect to the subject's own position. It has been successfully applied to people with more than ten years of schooling.

4.12 Gottschaldt Figures Test

The Gottschaldt Figures Test (GFT) is a test of analytical perceptual ability. The subject's task is to identify which of five key shapes are embedded within a more complex figure. It is appropriate for matriculants.

4.13 Rotate and Flip Test

The Rotate and Flip Test (RAFT) is a measure of visualization i.e. the ability to mentally twist and rotate parts of an object to form a complete whole. The test can be applied to people with ten or more years of schooling. This is a newly developed test.

4.14 F-test

The F-test is a subtest of the original General Aptitude Test Battery (GATB) (United States Employment Service, 1967). It is a measure of spatial ability. The subject's task is to "select which of the alternative figures has the same parts as the stimulus figure, with the parts however being either rearranged or re-oriented" (Epstein, 1983, p.143). Thus is appears to be a two-dimensional visualization task. The test has been used successfully on first-year engineering students.

4.15 H-test

The H-test is a test of surface development based on a subtest of the GATB. The task involves mentally folding/rolling a flat shape along specified lines to create a three-dimensional object and indicating which of four alternatives can be made from the stimulus. The task appears to incorporate both visualization and spatial relations and orientation. The test has been used on both Blacks and White University students.

4.16 Mechanical Comprehension Test

The Mechanical Comprehension Test (A3/1) measures the ability to apply the principles of physics appropriately. The content area of the test is largely general physics and applied mechanics. It is suitable for people with ten or more years of schooling.

4.17 General Science Test

The General Science Test consists of two parts: a Technical and Scientific Knowledge Test (SKT) and a Technical Reading Comprehension Test (TRC). It is suitable for people with at least twelve years of schooling.

5. VALIDATION OF THE ARITHMETIC REASONING TESTS AND ESTIMATION TEST

For each test (ART-HL, ART-SL and ET-HL) a description will be given of the samples followed by the basic statistics obtained from the samples. Thereafter for each study data relating to construct validity will be presented, and then data relating to predictive validity.

5.1 Validation of the ART-HL

5.1.1 Description of the samples

5.1.1.1 Sample 1

In 1981 the ART-HL was applied to 125 White students studying computer science at a university. The ratio of English to Afrikaans students was 2:1. Most of the students were studying in the Commerce Faculty, substantially fewer in the Science Faculty and even less in the Arts Faculty. The students were all undergraduates, mostly in their first year of study. In this sample the 36-item version of the test was applied but analysis was performed on the 24 relevant items.

5.1.1.2 Sample 2

Sample 2 consisted of 109 people from industry being trained in programming techniques. Applicants were thoroughly screened before acceptance on the course. Preacceptance screening consisted of five tests from the Burrough's Computer Battery (Verbal Memory, Reasoning, Letter Sequencing, Numeracy and Diagrams), a test specially constructed by the organization and an interview.

5.1.1.3 Sample 3

The ART-HL was used as part of a battery for the selection of students for the Master of Business Administration degree.

Students are generally graduates although exceptions are made. The test was applied to 227 applicants.

5.1.1.4 Sample 4

Sample 4 comprised 65 accountancy students studying for an honours degree at an Afrikaans university.

5.1.2 Basic statistics of the ART-HL

Only the test statistics based on entire samples are presented below. Statistics based on subsamples are discussed together with the validation results. The number of subjects in each sample, mean, standard deviation, range and available reliabilities (Kuder-Richardson formula 20, Kuder-Richardson formula 21 and Kuder-Richardson formula 21 with Tucker's correction for normal distribution) are presented in Table 2.

TABLE 2

SAMPLE SIZE, MEAN, STANDARD DEVIATION, OBTAINED RANGE AND RELIABILITY COEFFICIENTS FOR THE ART-HL BASED ON FOUR SAMPLES

SAMPLE	N	$\bar{X}$	SD	OBTAINED RANGE		KR_{20}	KR_{21}	KR_{21}(corrected)
				MIN	MAX			
1	125	10,3	5,15	0	21	-	0,812	0,838
2	109	11,44	3,95	1	24	-	0,642	0,687
3	227	11,24	5,26	0	23	-	0,818	0,843
4	65	11,14	4,51	3	20	0,78	-	-

The subjects in the four samples have all had twelve years or more schooling and can be regarded as "university material". The ART-HL appears to be at the appropriate level of difficulty for this type of subject. For all samples scores encompass the entire range with the mean approximately in the middle of the range. The reliabilities are acceptable particularly considering that the samples are already highly selected. Subjects in Sample 2, for example, were selected on the basis of six tests and an interview. Furthermore, the KR_{21} formula is an underestimate of KR_{20} which is a more accurate measure of reliability since it takes item statistics into account.

5.1.3 **Validation studies based on ART-HL**

5.1.3.1 Sample 1*

The students tested on the ART-HL were studying a computer science course which varied for different groups of students. Some students were obliged to complete a basic course in computer science to fulfil the requirements for their degree, while for other students it was an elected course.

In addition to the ART-HL, the students were tested on the DRT-HL, GFT, CRT (original 52-item version) and MA-HL. The intercorrelation matrix between these tests is presented in Table 3.

* Much of the data on which this study is based was obtained from a report by Calitz, A.P.

TABLE 3

INTERCORRELATION MATRIX BETWEEN ART-HL, MA-HL,DRT-HL, GFT AND CRT, SAMPLE 1, VARIABLE N, 65<N<88

	ART-HL	MA-HL	DRT-HL	GFT	CRT
ART-HL	-				
MA-HL	0,52**	-			
DRT-HL	0,47**	0,62**	-		
GFT	0,31**	0,45*	0,27*	-	
CRT	0,42**	0,48**	0,25*	0,51*	-

* Indicates significance at the 0,05 level
** Indicates significance at the 0,01 level

The ART-HL correlates significantly with all the other tests. The poorest correlation is with GFT (r = 0,31) which is understandable considering that this test measures largely in the perceptual domain. The correlations of 0,52 with MA-HL and 0,47 with DRT-HL indicate a substantial reasoning component.

Subgroups of the main sample were extracted to create smaller groups who had completed the same course. Correlations were calculated between ART-HL and various different criteria. Table 4 provides the criterion, number of subjects within the subgroup, correlation with ART-HL, the mean and standard deviation of the test and the standard deviation of the criterion. The first four criteria (Mathematics-HG and SG, Science and Accountancy-HG) are matriculation symbols ranging from 2(<33,3%) to 8 (>,80%). For the final criterion a coding was used. The code was one for a person who dropped out of the course, two for those who scored less than 60 per cent in the November examinations and three for those who scored 60 per cent or more in the November examinations.

TABLE 4

CRITERION, NUMBER OF SUBJECTS, CORRELATION WITH ART-HL, MEAN AND STANDARD DEVIATION OF THE ART-HL AND STANDARD DEVIATION OF THE CRITERION FOR SAMPLE 1

CRITERION	N	r	$\bar{x}$ ART	σ ART	σ CRITERION
Mathematics-HG	65	0,40**	12,37	4,92	1,42
Mathematics-SG	40	0,09	8,20	4,62	1,58
Science-HG	74	0,43**	11,37	5,15	1,25
Accountancy-HG	59	0,38**	9,72	5,14	1,32
B Com Computer Science Introductory Course	62	0,04	9,68	4,97	14,11
B Sc Computer Science Marks, July	19	0,62**	12,21	5,06	15,69
B Sc Computer Science Marks, November	17	0,55*	12,12	4,78	14,15
Coding of 1 drop out					
2 mark <60%	23	0,56**	11,61	4,87	2,26
3 mark ≥60%					

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level

The mean of the ART-HL varies from 8,2 for students who studied standard grade mathematics at school to 12,37 for students who studied high grade mathematics at school. The fact that the test is able to distinguish groups of students studying high grade or standard grade mathematics provides reassuring evidence that it is measuring within the numerico-logical domain.

Two sets of correlations are of particular interest. The first set is between ART-HL and Mathematics-HG (r = 0,40) and ART-HL and Mathematics-SG (r = 0,09). The second set is between the ART-HL and the B Com Computer Science Introductory Course (r = 0,04) and the ART-HL and the B Sc Computer Science course marks for July and November (r = 0,62 and 0,55 respectively). For both sets of correlations the disparity between the coefficients can be attributed to the nature of the criterion. In Mathematics-SG scholars are taught routine strategies to follow in given situations whereas in Mathematics-HG a greater level of conceptualization is required. Scholars are expected to adapt formulae to deal with non-standard situations. One would expect a measure of arithmetical conceptual ability to correlate better with a criterion which requires that ability than one which does not. The first set of correlations fulfill this expectation. A similar explanation can be used to explain the second set of correlations. An examination of the computer science syllabus for the B Com students shows that although there is an overlap with the B Sc course, it is less conceptually demanding.

These two sets of correlations and the evidence provided by the variation in the mean provide confirmation of the construct validity of the test.

A final statistic of note is the correlation of 0,56 between the ART-HL and the code of one (dropout) two (mark less than 60 per cent in November examinations) and three (mark greater than or equal to 60 percent in November examinations) which confirms the test's ability to discriminate successful from unsuccessful students.

5.1.3.2 Sample 2

Testing on Sample 2 took place at the beginning of 1982. In addition to the preacceptance screening, the students were given seven NIPR tests. These tests were MA-HL, DRT-HL, FCT-HL (shortened 18-item version), WICT, RAFT, ET-HL (an early version later considerably modified) and the ART-HL. The criterion was the marks (as a percentage) obtained at the end of the course.

The means, standard deviations and ranges are given in Table 5. "Passes" refers to those people who passed the class test and "failures" refers to those who did not.

TABLE 5

MEANS, STANDARD DEVIATIONS AND OBTAINED RANGES FOR THE ART-HL, SAMPLE 2

	N(*)	$\bar{X}$ ART	σ ART	OBTAINED RANGE MIN	OBTAINED RANGE MAX
Total Group	111	11,44	3,95	2	20
Passes	89	11,86	3,98	2	20
Failures	20	9,55	3,35	4	15

(*) NOTE : Two students did not complete the course

The mean of the test for the total group lies very close to the middle of the overall test range whilst the obtained test scores encompass almost the entire possible range. It would appear that the test was at the correct difficulty level. It should be noted that the mean for those who passed the course is over two points higher than for those who failed the course. All the variables were intercorrelated. Since the criterion (course marks) was severely restricted in range, those who failed were coded 1 and those who passed were coded 2. The correlation was then performed on the criterion as a dichotomous variable. This matrix is presented in Table 6.

TABLE 6

INTERCORRELATION MATRIX BETWEEN MA-HL DRT-HL, WICT, RAFT, ET-HL, ART-HL AND PASS/FAIL CRITERION, SAMPLE 2, N = 109

	MA-HL	DRT-HL	FCT-HL	WICT	RAFT	ET-HL	ART-HL	PASS FAIL
MA-HL	-							
DRT-HL	0,3868**	-						
FCT-HL	0,4911**	0,4404**	-					
WICT	0,3396**	0,3819**	0,3148**	-				
RAFT	0,3171**	0,2396*	0,3911**	0,2823**	-			
ET-HL	0,4242**	0,1970*	0,3603**	0,1301	0,2095*	-		
ART-HL	0,3983**	0,1201	0,3256**	0,1664	0,1771	0,5368**	-	
PASS/ FAIL	0,2287*	-0,0078	0,1564	0,0391	0,1407	0,1024	0,2271*	-

* Indicates significance at 0,05 level

** Indicates significance at 0,01 level

Both ART-HL and ET-HL are numerical tests with a reasoning component. This is reflected in the substantial correlation of the two tests with each other and the slightly smaller but nevertheless strong correlations of both tests with MA-HL and FCT-HL. The low correlation of the ART-HL with DRT-HL is perplexing as this is a reasoning test. It measures only syllogistic reasoning however: this type of reasoning apparently is not involved in ART-HL. The correlation between DRT-HL and ET-HL just reaches significance at the five per cent level. Thus syllogistic reasoning does not appear to be an important aspect of the ability to estimate. The correlations of the ART-HL and ET-HL with verbal and spatial tests are low. This fact, together with the substantial correlation between ART-HL and ET-HL constitute evidence of construct validity.

The correlations between the tests and the pass/fail criterion are disappointingly low. The generally low correlations may be attributed to two factors, firstly, the sample was highly selected on the basis of five other tests and an interview. The restriction in the sample will reduce correlation coefficients. Secondly, a Pearson Product Moment correlation was performed. If one of the variables is dichotomous this will provide an underestimate of the correlation. In the light of the highly selected nature of the sample and the type of correlation computed, the performances of the ART-HL and MA-HL are creditable.

5.1.3.3 Sample 3

The ART-HL was used as part of a battery for the selection of students for the Master of Business Administration degree. The test battery consisted of MA-HL, RC-HL, ART-HL and CRT-HL. These tests were applied to 227 MBA applicants and the results were correlated with matriculation marks for mathematics (high grade) and science (high grade). The intercorrelation matrix is presented in Table 7.

TABLE 7

INTERCORRELATION MATRIX BETWEEN MATHEMATICS-HG, SCIENCE-HG MA-HL, RC-HL, ART-HL, AND CRT-HL, SAMPLE 3, N=227

	Maths-HG	Science-HG	MA-HL	RC-HL	ART-HL	CRT-HL
Maths-HG	-					
Science-HG	0,7057**	-				
MA-HL	0,4198**	0,3460**	-			
RC-HL	0,3041**	0,3348**	0,4817**	-		
ART-HL	0,4599**	0,4052**	0,6036**	0,2917**	-	
CRT-HL	0,3699**	0,2265**	0,5502**	0,2635**	0,5406**	-

** Indicates significance at the 0,01 level

The correlations between the ART-HL and the other tests show that the ART-HL covaries most with MA-HL (which has logical and numerical components), less with CRT-HL (which is non-verbal and has a smaller numerical component) and least with RC-HL. This is what one would expect from a test of arithmetic reasoning ability.

The correlations between ART-HL and the Mathematics-HG and Science-HG criteria indicate the ability of ART-HL to predict success in the more "exact" disciplines. The ART-HL correlates more highly with mathematics-HG ($r = 0{,}4052$) but both of these correlations are substantial and higher than the correlations of the other tests with the criteria.

The correlations of the ART-HL both with other tests and with the criteria support earlier evidence that the test is a measure of arithmetic reasoning ability.
Of the 227 applicants, a third were rejected on the basis of test results. Further selection was based on other factors. A second intercorrelation was performed based on the successful MBA applicants and their end of year examination results. The courses completed by the students and the abbreviations of those courses are listed below :

Computer Applications in Business	Comp App
Financial Accounting	Fin Acc
Human Behaviour	Hum Behav
Industrial Relations	Indus Relat
Legal Environment of Business	Legal Env
Management Accounting	Manag Acc
Mathematics and Statistics	Maths Stats
Operational Marketing Management	Op Mkt Man
Operations Research	Oper Res
Personnel Management	Pers Manag
Principles of Marketing Management	Prin Mkt Man

The intercorrelation matrix is presented in Table 8.

TABLE 8

INTERCORRELATION MATRIX BETWEEN MA-HL, RC-HL, ART-HL, CRT-HL, AGE AND ELEVEN COURSE RESULTS, SAMPLE 3, N=68 VARIABLE N, 59<N<68

	MA-HL	RC-HL	ART-HL	CRT-HL	AGE
MA-HL	-				
RC-HL	0,2330	-			
ART-HL	0,1703	-0,2461*	-		
CRT-HL	0,3076*	-0,0532	0,3426**	-	
AGE	-0,0797	-0,0766	-0,1009	-0,2026	-
COMP APP	0,2248	0,0144	0,2785*	0,2855*	-0,1234
FIN ACC	0,2705*	0,0212	-0,0035	0,0521	-0,1821
HUM BEHAV	0,0292	-0,0356	0,1561	0,0439	0,0716
INDUS RELAT	-0,0869	0,0387	-0,1079	-0,3283**	0,3103*
LEGAL ENV	-0,1224	0,0123	0,1822	0,0850	-0,1708
MANAG ACC	-0,0257	-0,0879	0,0605	-0,0170	-0,1170
MATHS STATS	0,4170**	-0,0182	0,4003**	0,3462**	-0,2314
OP MKT MAN	0,1132	0,1777	0,0007	-0,0225	0,0725
OPER RES	0,3468**	-0,0403	0,2673*	0,2765*	-0,0472
PERS MANAG	0,1079	-0,1150	0,0796	-0,1354	-0,0716
PRIN MKT MAN	0,1218	-0,0183	0,1076	-0,0421	0,0620

* Indicates significance at 0,05 level

** Indicates significance at 0,01 level

This intercorrelation is based upon the 68 part-time students who form the bulk of the first-year MBA students. Of the eleven criteria used, three have particularly high quantitative and conceptual elements viz. Computer Applications in Business, Mathematics and Statistics and Operations Research. The ART-HL correlates significantly only with these three criteria. Subjects which require a high quantitative ability but a low conceptual ability such as Financial Accountancy and Management Accounting do not correlate with the ART-HL. The correlations with Computer Applications in Business, Mathematics and Statistics and Operations Research are noteworthy when one considers that they are based upon a highly selected sample.

The effects of restriction of range can be seen in the drop in correlation between ART-HL and CRT-HL for the applicant group (r = 0,5406) and the selected students (r = 0,3428). Consequently, the correlations of ART-HL with the criteria would probably be substantially larger if the variables had a less restricted range due to selection.

A noteworthy correlation is that between the ART-HL and age. The correlation of -0,1009 is non-significant. Thus recency of schooling does not seem to influence test results. This is not surprising since the test items are presented in a novel format, thereby preventing the use of rote procedures in working out the solutions.

5.1.3.4 Sample 4

The ART-HL was used together with ET-HL(40-item version), A15 and DRT-HL to predict course marks for B Com (Hons) students studying accountancy at an Afrikaans university. Course marks were obtained for the following subjects :

Accountancy 1	Acc 1
Auditing 1	Aud 1
Income Tax 1	Tax 1
Public Accountancy 1	Pub Acc 1
Accountancy 2	Acc 2
Auditing 2	Aud 2
Income Tax 2	Tax 2
Public Accounting 2	Pub Acc 2

The intercorrelation matrix is presented in Table 9.

TABLE 9

INTERCORRELATION MATRIX BETWEEN ART-HL, ET-HL, A15, DRT-HL AND EIGHT COURSE RESULTS, SAMPLE 4, VARIABLE N,$47 \leq N \leq 65$

	ACC1	AUD1	TAX1	PUBACC1	ACC2	AUD2	TAX2	PUBACC2	ART-HL	ET-HL	A15	DRT-HL
ACC1	-											
AUD1	0,5825**	-										
TAX1	0,7481**	0,5754**	-									
PUBACC1	0,4540**	0,4206**	0,3832**	-								
ACC2	0,6983**	0,6604**	0,4933**	0,4527**	-							
AUD2	0,4382**	0,8381**	0,5274**	0,4641**	0,7438**	-						
TAX2	0,6217**	0,7211**	0,5411**	0,5352**	0,8414**	0,7689**	-					
PUBACC2	0,6207**	0,6426**	-0,4881**	0,5617**	0,8315**	0,6945**	0,7276**	-				
ART-HL	0,0234	0,0633	-0,0579	0,2418	-0,2247	-0,0930	-0,3028	0,0639	-			
ET-HL	0,2834*	0,3288**	0,2796**	0,3847**	0,2787	0,2847	0,2848	0,4243**	0,3875**	-		
A15	0,1676	0,1413	0,0120	0,3288**	0,0174	0,0045	-0,1126	0,1311	0,5290**	0,1753	-	
DRT-HL	0,2227	0,1811	0,1919	0,1097	0,1623	0,1809	0,2131	0,2157	0,2972*	0,4725**	0,4157**	-

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level

The ART-HL correlates significantly with ET-HL and A15 and to a lesser extent with DRT-HL. These correlations are large considering the highly selected nature of the sample. The only significant correlation of the ART-HL with the criteria is negative. This duplicates the results found in Sample 3: activities such as accountancy which have high numerical demands but low conceptual ones are not predicted by the ART-HL.

On the other hand ET-HL correlates significantly with five of the eight criteria and just misses correlating significantly with the other three criteria. Thus where the task places high numerical demands but low conceptual demands on the individual ET-HL is a useful test.

In a second testing session the revised version of ET-HL (26 items) was applied to a similar group of students (n = 72). The test mean for this group was 17,28 and the obtained range was 9 to 25 i.e. the test was slightly negatively skewed. The Kuder-Richardson formula 21 reliability was 0,625. This rose to 0,677 when Tucker's correction for normal distribution was applied. These relatively low reliability coefficients may be attributed to the highly selected nature of the sample.

The end of year results were obtained for a subsample of this group (n = 42). The subjects were categorized into those who passed and those who failed (or did not write) the final examinations. A biserial correlation was computed on the data and was significant at the one per cent level. The ET-HL was useful in distinguishing passes from failures.

5.2 Validation of ART-SL

5.2.1 Description of samples

5.2.1.1 Sample 5

The ART-SL was applied to 91 male technikon and technical college students. The students had been selected prior to the testing session on the basis of their results on the General Science Test, Mechanical Comprehension Test and the Mental Alertness from the Intermediate Battery. The students were all males, in their first, second or third year of study. A second testing session was undertaken to increase the sample sizes for the purpose of constructing norms.

5.2.1.2 Sample 6

The ART-SL was applied to 103 White male and female government school pupils in Standards 8, 9 and 10.

5.2.1.3 Sample 7

A battery of tests, which included the ART-SL, was applied to the 1983 and 1984 matriculation classes at a private school for boys, some of whom were boarders.

5.2.1.4 Sample 8

A 36 item version of the ART-SL was applied to 136 Black students at a technikon. These students were tested on a variety of NIPR tests prior to a year of pre-technikon training. They were all male matriculants.

5.2.1.5 Sample 9

A 19-item version of the ART-SL, together with a number of other NIPR tests, was applied to a large group of Black applicants for training as technicians. Ninety per cent of the Blacks were between the ages 18-29 years, they were largely urban and they all had ten to twelve years of schooling.

5.2.1.6 Sample 10

A sample of 108 Black bursary applicants was tested on several NIPR and Human Sciences Research Council (HSRC) tests. The students were either matriculants or in their matriculation year. The sample consisted of both males and females. The bursaries were for first year positions in the Commerce Faculty of a university.

5.2.2 **Basic Statistics of the ART-SL**

The number of subjects in each sample, mean, standard deviation, range and internal reliability (Kuder-Richardson formula 21 and Kuder-Richardson formula 21 with Tucker's correction for normal distribution) for the ART-SL based on the samples is presented in Table 10.

TABLE 10

SAMPLE SIZE, MEAN, STANDARD DEVIATION, OBTAINED RANGE AND RELIABILITIES (KR_{21} AND KR_{21} CORRECTED) FOR THE ART-SL

	N	$\bar{x}$	sd	OBTAINED RANGE MIN	MAX	KR21	KR21 (corrected)
Sample 6	103	15,88	7,13	2	30	0,882	0,899
Sample 7	185	17,56	7,82	2	30	0,892	0,906
Sample 8	136	15,09	8,04	0	30	0,914	0,927
Sample 9a(*)	87	10,52	5,45	0	19	0,889	0,908
9b	137	4,84	4,24	0	19	0,844	0,875
Sample 10	108	10,81	5,70	0	27	0,815	0,841

(*) Sample split : 9a = Matriculants, 9b = Standard 8 + 9
19-Item Test Used.

The ART-SL performed satisfactorily on these samples. In all

The ART-SL performed satisfactorily on these samples. In all samples except Samples 9b and 10 the mean is near the middle of the range. The obtained ranges cover virtually the entire possible range. The test is clearly too difficult for the standard 8 and 9 Black pupils. It proved slightly too difficult for the Black matriculants who form Sample 10, but where selection is at the top end of the sample the test should prove very useful. These figures indicate that the ART-SL is appropriate for Whites with ten to twelve years of schooling and Blacks with at least twelve years of schooling. For all the samples the internal consistency of the test is high. Even for the 19-item version the high reliabilities are maintained.

5.2.3 Validation studies based on ART-SL

5.2.3.1 Sample 5

The subjects in Sample 5 had been preselected on the basis of their results on the General Science Test, Mechanical Comprehension Test and the Mental Alertness from the Intermediate Battery. At a later testing session the ART-SL, ET-HL and Embedded Problems Test were administered. Below is the intercorrelation matrix based on the complete sample.

TABLE 11

INTERCORRELATION MATRIX AMONG SEVEN NIPR TESTS, SAMPLE 5, VARIABLE N, 64<N<91

	MA-I	BLOX	A3/1	GST	ART-SL	ET-HL	EPT
MA-I	-						
BLOX	0,3378**	-					
A3/1	0,5258**	0,5444**	-				
GST	0,3387**	0,0949	0,2017	-			
ART-SL	0,4211**	0,2163	0,3883*	0,1085*	-		
ET-HL	0,3738**	0,2090	0,2712*	0,2439	0,4504**	-	
EPT	0,3433**	0,0515	0,4201**	0,2785*	0,4378**	0,5373**	-

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level

Note : Correlations were performed on stanines for all preselection tests.

The intercorrelation between ART-SL and six other NIPR tests shows a similar pattern to that found in other samples, viz. the ART-SL correlates most strongly with the tests of number ability (ET-HL and EPT), slightly less with the test of general intellectual functioning (MA-I) and to a non-significant extent with the Blox or General Science Test. The Mechanical Comprehension Test (A3/1) is partially a measure of reasoning ability and thus one would expect the low but significant correlation that was obtained (r = 0,3883).

The ET-HL shows a similar pattern of intercorrelation to the ART-SL except that the correlations with MA-I and A3/1 are slightly lower, reflecting the lower reasoning ability component of ET-HL.

For predictive validation purposes a subgroup of the main sample was extracted, since the main sample comprised students in their first, second and third years of study at both a Technikon and a Technical College. The largest subgroup was the first year Technikon students of whom there were 32. Criterion data was obtained in the form of examination results in six subjects. These subjects were Digital Systems (Digit Sys), Electrical Engineering (Elec Eng), Industrial Technology (Indus Tech), Engineering Mathematics (Eng Maths), Communication (Comm) and Electronics (Electro). The intercorrelation matrix based on the tests and the criteria is presented in Table 12. The results in this table must be regarded as tentative because of the small sample size.

TABLE 12

INTERCORRELATION MATRIX BETWEEN NIPR TESTS AND SIX CRITERIA, SAMPLE 5, VARIABLE N, 20≤N≤32

	GST	BLOX	A3/1	MA-I	DIGIT SYSTEM	ELEC ENG	INDUS TECH	ENG MATHS	COMM	ELECTRO	ART-SL	ET-HL	EPT
GST	-												
BLOX	-0,4866*	-											
A3/1	-0,0809	0,4259*	-										
MA-I	0,3291	0,0676	0,3219	-									
DIGIT SYS	0,1521	0,2681	0,3940	0,2744	-								
ELEC ENG	-0,0113	0,5033*	0,3777	-0,0382	0,7186**	-							
INDUS TECH	0,3590	0,1167	0,5560**	0,5079*	0,7381**	0,5891**	-						
ENG MATHS	-0,1414	0,5299*	0,5004*	0,1177	0,7109**	0,7978**	0,5651**	-					
COMM	0,2536	0,1491	0,4603*	0,4570*	0,3356	0,5256**	0,7405**	0,4469	-				
ELECTRO	0,0325	0,3865	0,2721	0,1546	0,6037	0,7652**	0,5590**	0,7229**	0,6668**	-			
ART-SL	-0,2310	0,4498*	0,3708	0,3029	0,5938**	0,3892	0,5387**	0,5860**	-0,0285	0,1843	-		
ET-HL	0,2235	0,2304	0,2828	0,5689**	0,4360*	0,3175	0,5658**	0,3409	0,3801	0,4484*	0,2568	-	
EPT	0,2950	-0,2042	0,5117**	0,3044	0,6351**	0,3931	0,5316**	0,3937	0,3649	0,4704*	0,1867	0,4005*	-

* Indicates significance at 0,05 level

** Indicates significance at 0,01 level

The intercorrelation between ART-SL, ET-HL and the criteria can be explained in part by the nature of the criteria. The ART-SL correlates at the one percent level of significance with Digital Systems and Engineering Mathematics, both of which require a high level of numerical and conceptual ability, but not at all with Communication (a course in grammar). The Electronics course appears to require a great deal of rote learning of facts, thus one would not expect it to correlate with the ART-SL. The ART-SL's correlation with the other two criteria (Electrical Engineering and Industrial Technology) is less easy to explain. There appears to be no good reason why a test of arithmetic reasoning ability should correlate substantially (r = 0,5887) with a practical course based on workshop practice, materials technology, components, p.c. boards etc. Conversely, one would expect such a test to correlate more highly than the nonsignificant 0,3892 with a course in Electrical Engineering. However, two facts must be borne in mind. Firstly the subjects had already been selected on the basis of four tests. Secondly, the sample size is small, ranging from 20 to 32.

The ET-HL correlates significantly with three of the six criteria: Digital Systems, Industrial Technology and Electronics. The correlation with Industrial Technology remains inexplicable. The correlation of Digital Systems with ET-HL is lower than that with ART-SL which reflects the limited extent to which ET-HL measures conceptual ability. The Electronics course requires rote learning, an ability which ET-HL appears to be able to measure. The cognitive demands of both Electrical Engineering and Engineering Mathematics are not measured by ET-HL. The lack of correlation with Communication is expected.

5.2.3.2 Sample 6

The ART-SL was applied to 103 male and female White school pupils in standard 8, 9 and 10. The basic statistics for the test, based on the students in each standard, are presented in Table 13.

TABLE 13

CLASS STANDARD, SAMPLE SIZE, MEAN, STANDARD DEVIATION AND RANGE OF THE ART-SL, SAMPLE 6

CLASS STANDARD	N	$\bar{X}$	SD	OBTAINED RANGE MIN	MAX
8	40	15,425	6,66	3	29
9	32	16,281	7,37	2	30
10	31	16,065	7,75	4	29

It is noteworthy that the influence of education appears to be minimal. This is confirmed by the correlation of 0,0395 between ART-SL and education level (See Table 14).

The ART-SL was correlated with mathematics and science marks. Since the students had written different mathematics and science examinations their results were first standardized so as to be comparable before a correlation was performed. The correlation matrix is presented in Table 14.

TABLE 14

INTERCORRELATION MATRIX BETWEEN MATHEMATICS, SCIENCE, SEX, EDUCATION AND ART-SL, SAMPLE 6, N = 103

	MATHS	SCIENCE	SEX	EDUC	ART-SL
MATHS	-				
SCIENCE	0,6433**	-			
SEX	0,1384	0,0344	-		
EDUC	-	-	-0,1000	-	
ART-SL	0,4533**	0,4180**	-0,0438	0,0395	-

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level

The ART-SL showed no sex-linked bias and, as mentioned earlier, is relatively unaffected by education provided it is used at the correct level (ten to twelve years schooling). The ART-SL correlates at the one percent level of significance with both mathematics and science (r = 0,4533 and r = 0,4180 respectively). This provides good evidence of its validity.

5.2.3.3 Sample 7

The ART-SL was applied, together with other NIPR tests, to the 1983 and 1984 matriculation classes at a private school for boys.

Apart from the ART-SL, tests from the High Level Battery were applied viz. Mental Alertness, Arithmetic Problems, Reading Comprehension and Vocabulary. In addition the intermediate level of the Deductive Reasoning Test and the Computation Test, and the Estimation Test - High Level were applied. School results in the form of Std 9 end of year mathematics marks and Std 10 first term mathematics examination marks were obtained. Results from students studying standard grade mathematics were analysed separately from those studying high grade mathematics. In Table 15 the basic statistics for the ART-SL are presented for the two groups.

TABLE 15

SAMPLE SIZE, MEAN, STANDARD DEVIATION AND RANGE FOR STUDENTS STUDYING MATHEMATICS-SG OR MATHEMATICS-HG, SAMPLE 7

	N	$\bar{X}$	SD	OBTAINED RANGE	
				MIN	MAX
Mathematics-SG	60	13,01	6,04	2	27
Mathematics-HG	125	19,74	6,86	2	30

The difference in the mean of nearly seven marks shows that students studying standard grade mathematics do significantly worse on the test than students studying high grade mathematics.

The intercorrelation matrices based upon test scores and school marks in mathematics are presented in Tables 16 and 17.

TABLE 16

INTERCORRELATION MATRIX OF SCHOOL MARKS AND TEST SCORES BASED ON SCHOLARS STUDYING MATHEMATICS-SG, SAMPLE 7, N = 60

	MATHS-9	MATHS-10	MA-HL	AP-HL	RC-HL	VOC-HL	A15	CT	ART-SL	ET
MATHS-9	-									
MATHS-10	-0,3191*	-								
MA-HL	-0,3254*	0,0584	-							
AP-HL	-0,3018*	0,1159	0,4486**	-						
RC-HL	-0,2094	0,0309	0,2648*	0,3707**	-					
VOC-HL	-0,1804	0,1166	0,0156	0,0515	0,2147	-				
A15	-0,0433	0,1220	0,4904**	0,2219	-0,0643	-0,0218	-			
CT	-0,2264	-0,1757	0,1294	0,2222	0,0113	-0,1834	0,0653	-		
ART-SL	-0,0906	0,1769	0,2995*	0,4125**	-0,0439	0,0783	0,3131*	0,2393	-	
ET-HL	0,0017	-0,0048	0,1584	0,2151	0,1543	0,0570	0,1467	0,2711*	0,3278*	-

* Indicates significance at 0,05 level

** Indicates significance at 0,01 level

TABLE 17

INTERCORRELATION MATRIX OF SCHOOL MARKS AND TEST-SCORES BASED ON SCHOLARS STUDYING MATHEMATICS, SAMPLE 7, N = 125

	MATHS-9	MATHS-10	MA-HL	AP-HL	RC-HL	VOC-HL	A15	CT	ART-SL	ET-HL
MATHS-9	-									
MATHS-10	0,7858**	-								
MA-HL	0,5196**	0,4186**	-							
AP-HL	0,5202**	0,5219**	0,6439**	-						
RC-HL	0,3541**	0,3324**	0,4134**	0,3551**	-					
VOC-HL	0,2904**	0,3648**	0,4588**	0,4181**	0,5257**	-				
A15	0,2053**	0,2252**	0,4046**	0,4002**	0,1900	0,2387**	-			
CT	0,4003**	0,3538**	0,4650**	0,4978**	0,1688	0,1623	0,2028*	-		
ART-SL	0,5375**	0,4989**	0,5145**	0,4479**	0,2474**	0,3229**	0,2658**	0,4336**	-	
ET-HL	0,4766**	0,4706**	0,5203**	0,5603**	0,1571	0,2235*	0,1802*	0,4371**	0,4507**	-

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level

Certain patterns of intercorrelations should be noted in Tables 16 and 17. First the relationship of the ART-SL with other tests will be examined and then the correlations with the criteria. In Table 16 the ART-SL correlates at the one percent level of significance with AP and at the five percent level with MA-HL, A15 and ET-HL. It narrowly misses correlating significantly with the Computation Test and shows absolutely no relationship with either Reading Comprehension or Vocabulary. The correlations of variables in the Mathematics-HG group (Table 17) are of a higher order than those of the Mathematics-SG group. This seems to indicate that the intellectual functioning of the Mathematics-HG group is more integrated. They use their logical reasoning ability on all the tests they were given. Nevertheless the pattern of intercorrelations in the two groups is similar. The ART-SL correlates most highly with Mental Alertness-HL, closely followed by ET-HL, Arithmetic Problems and the Computation Test. Although significant at the one percent level, the correlations between ART-SL and Reading Comprehension-HL and Vocabulary-HL are markedly lower than the correlations with the other tests.

The intercorrelations obtained in Tables 16 and 17 confirm the construct validity of the ART-SL. The test correlates well with numerical and also reasoning tests, especially in the Mathematics-HG group. The test predicts mathematics-HG scores more effectively than mathematics-SG scores, presumably because the former is more conceptual. This finding is similar to the finding in Sample 1 that the ART-HL correlated significantly with Mathematics-HG and not at all with Mathematics-SG.

The correlations of ET-HL with other tests in the Matnematics-SG group are nonsignificant except for those with the Computation Test and ART-SL. The correlations in the Mathematics-HG group are more substantial. Correlations with Mental Alertness-HL, Arithmetic Problems-HL, Computation Test and ART-SL are significant at the one percent level. The correlations with the language tests and non-verbal reasoning are markedly lower.

5.2.3.4 Sample 8

A 36-item version of the ART-SL was applied to 136 Black students at a Technikon. A 30-item test was made from the 36 items and this was used in the intercorrelation matrix. The students were tested on a variety of NIPR tests prior to a year of pre-Technikon training. The tests used were the Mental Alertness (Intermediate Level), Arithmetic Problems (Intermediate Level), Blox Test, Gottschaldt Figures Test, Technical Reading Comprehension, F-Test, H-Test, Mechanical Comprehension Test, ART-SL and the Deductive Reasoning Test (Intermediate Level). Criteria in the form of end of year examination results were obtained for five subjects. These were Preliminary Mathematics (P MATHS), Chemistry (CHEM), Applied Science (APP SC), Preliminary Drawing (P DRAW) and Communication (COMM). An average (AV) based on these five subjects was calculated. The correlation matrix based on these variables is presented in Table 18.

TABLE 18

INTERCORRELATION MATRIX BETWEEN NIPR TESTS AND FIVE CRITERIA,

SAMPLE 8, N = 136

	MA-I	AP-I	BLOX	GFT	TRC	F-TEST	H-TEST	A3/1	ART-SL	DRT-I
MA-I	-									
AP-I	0,6137**	-								
BLOX	0,2623**	0,3089**	-							
GFT	0,3451**	0,2498**	0,3337**	-						
TRC	0,5426**	0,5261**	0,2276**	0,2089*	-					
F-TEST	0,3539**	0,3361**	0,4096**	0,3388**	0,2167*	-				
H-TEST	0,3569**	0,3596**	0,5686**	0,3954**	0,1712	0,5884**	-			
A3/1	0,3153**	0,3587**	0,4402**	0,3330**	0,3508**	0,4202**	0,4871**	-		
ART-SL	0,5650**	0,5319**	0,2681**	0,3198**	0,3406**	0,3645**	0,3196**	0,2113*	-	
DRT-I	0,4950**	0,3681**	0,3336**	0,1671	0,2947**	0,2896**	0,2432**	0,2333	0,2738**	-
P MATHS	0,3760**	0,3594**	0,1756*	0,1052	0,3549**	0,2943**	0,1741*	0,2204	0,4330**	0,2590**
CHEM	0,3662**	0,2590**	0,1227	0,1341	0,3871**	0,2878**	0,0474	0,2539**	0,4190**	0,1406
APP SC	0,2567**	0,3164**	0,1258	0,0886	0,3269**	0,2606**	0,0625	0,2588**	0,4385**	0,0644
P DRAW	0,1565	0,1978*	0,4163**	0,1273	0,1273	0,3029**	0,4535**	0,1390	0,2736**	0,2345**
COMM	0,4850**	0,3814**	0,3560**	0,2123	0,5546**	0,3526**	0,3166**	0,3069**	0,3516**	0,2735**
AV	0,4166**	0,3988**	0,288588	0,1648	0,4342**	0,3872**	0,2473**	0,3088**	0,5219**	0,2512**

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level

Construct validity of the ART-SL was demonstrated by its relatively high correlations with Mental Alertness-Intermediate
Construct validity of the ART-SL was demonstrated by its relatively high correlations with Mental Alertness-Intermediate and Arithmetic Problems-Intermediate and lower correlations with the spatial tests, Technical Reading Comprehension, Mechanical Comprehension and Deductive Reasoning Test (Intermediate level).

Predictive validity for the ART-SL is equally clearly demonstrated. Correlations with the criteria are all significant at the one percent level. These correlations are particularly high for Preliminary Mathematics, Applied Science and Chemistry ($r = 0{,}4330$, $r = 0{,}4385$ and $r = 0{,}4190$ respectively). It has an understandably lower correlation with Communication ($r = 0{,}3516$) and the lowest correlation is with Preliminary Drawing ($r = 0{,}2736$). The correlation with the overall course average is high ($r = 0{,}5219$). The ART-SL was the best predictor - even than Mental Alertness (Intermediate) which has a wider variety of items.

5.2.3.5 Sample 9

A 19-item version of the ART-SL was applied to 252 Black male applicants for training as technicians. Other tests in the battery included the Mental Alertness-I, Mechanical Comprehension Test, F-test, H-test, Figure Classification Test, Blox, Technical Reading Comprehension, Poppelreuter, Gottschaldt Figures Test, Fault Finding Test and O'Connor Finger Dexterity Test. The Poppelreuter, Fault Finding Test and O'Connor Finger Dexterity Test are apparatus tests. The first two measure mechanical ability and the last measures finger dexterity with reference to instrument assembly work. Norms were calculated on this sample. Test results were used to reduce the sample to those worthy of further consideration. Subjects had to score a stanine of four or above on six tests, two of which had to be the tests of verbal and abstract reasoning, and three of which had to be the spatial tests. A final subsample of 75 applicants was selected from which a matrix of intercorrelations was computed. This matrix is presented in Table 19.

TABLE 19

MATRIX OF INTERCORRELATIONS BETWEEN NIPR TESTS, AGE AND EDUCATION, SAMPLE 9, N=75,

Tests	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Mental Alertness-I	-													
2 Mechanical Comprehension	0,25	-												
3 F Test	0,02	0,07*	-											
4 H Test	0,10	0,22*	0,45**	-										
5 Figure Classification Test-SL	0,50**	0,06	-0,01	0,02	-									
6 Blox	0,02	0,14	0,34**	0,42**	0,12	-								
7 Technical Reading Comprehension	0,40**	0,26**	0,02	0,00	0,11	-0,12	-							
8 Arithmetic Reasoning Test-SL (a)	0,49**	0,17	0,16	0,13	0,29**	0,07	0,38**	-						
9 Poppelreuter	0,21*	0,16	0,25*	0,29**	0,02	0,24	0,10	0,12	-					
10 Gottschaldt Figures Test (b)	0,31**	0,33**	0,36**	0,37**	0,07	0,28**	0,41**	0,33**	0,33**	-				
11 Fault Finding Test	0,03	0,31**	0,08	0,29**	-0,08	0,19	0,07	0,02	0,27*	0,18	-			
12 O'Connor Finger Dexterity	0,09	-0,07	0,21*	0,10	-0,16	0,14	-0,04	-0,11	-0,10	-0,01	0,10	-		
13 Age	-0,13	-0,17	-0,13	-0,17	-0,17	-0,11	-0,15	-0,17	-0,11	-0,25*	0,16	-0,19	-	
14 Education	0,21	0,24*	0,12	0,22	0,26*	0,15	0,06	0,24*	0,18	0,29**	0,10	0,05	-0,14	-

(a) n = 68
(b) n = 64
Source: Epstein, B.I. Factors related to mechanical aptitude in Blacks. Unpublished master's dissertation. University of South Africa, 1983.

The correlation of the ART-SL with tests of reasoning ability (Mental Alertness-I, Figure Classification Test) is high as is its correlation with analytic perceptual ability (Gottschaldt Figures Test). In this sample the correlation of the ART-SL with Technical Reading Comprehension is high, possibly due to the importance of analytic thinking in both tests. These figures together with the lack of correlation with mechanical and spatial tests, provide some evidence for the test's construct validity.

Performance on the ART-SL appears to be relatively unaffected by age but it does seem to be affected by education. This was noted earlier when it was shown that the test was too hard for those with less than twelve years of schooling.

5.2.3.6 Sample 10

A sample of bursary applicants was given a battery of NIPR and HSRC tests. The NIPR tests were the Mental Alertness and Reasoning Comprehension Tests from the High Level Battery and the ART-SL, while the HSRC tests were part of the Senior Aptitude Tests. The two tests used were Verbal Comprehension (VC) and Calculations (CALC). The final test was Mathematics-Diagnostic 1, (MD1) a specially devised test of computation ability.

Criteria were obtained in the form of school marks in Forms III, IV and V for mathematics (MATHSJC, MATHS IV, MATHS V), Science (SCIJC, SCI IV, SCI V) and an aggregate (JC-AV, IV-AV, V-AV). The criteria were coded : 1(<50%), 2(50 - 59%), 3(60 - 69%) and 4(70%).

The intercorrelation matrix between the tests and the criteria is presented in Table 20.

TABLE 20

INTERCORRELATION MATRIX OF TESTS AND CRITERIA. SAMPLE 10, N = 95

	MA-HL	RC-HL	MD1	ART-SL	VC	CALC	JC-AV	IV-AV	V-AV	MATHSJC
MA-HL	-									
RC-HL	0,1805	-								
MD1	0,4671**	0,0466	-							
ART-SL	0,5715**	0,0937	0,6062**	-						
VC	0,3698**	0,2434*	0,1847	0,2533*	-					
CALC	0,4026**	-,0127	0,6375**	0,3572**	0,1031	-				
JC-AV	0,1748	+0,0968	+0,2013	+0,2144*	+0,1844	+0,0072	-			
IV-AV	0,0495	-0,0618	-0,0187	+0,1572	+0,0979	-0,0446	0,4723**	-		
V-AV	-0,0918	-0,1484	+0,0500	+0,1206	-0,0633	-0,0770	0,1507	0,4136**	-	
MATHSJC	0,1155	-0,1160	+0,1358	+0,1394	+0,0580	+0,0436	0,3614**	0,2997**	0,1845	-
MATHSIV	0,0341	-0,0688	+0,2952**	+0,0382	+0 0524	+0,1897	0,2185*	0,2468*	0,0887	0,2852**
MATHSV(a)	0,0815	+0,0011	+0,2359*	+0,1417	+0,1114	+0,1419	0,0415	0,1705	0,3024**	0,1785
SCIJC(b)	0,1976	-0,0019	+0,0805	+0,0922	-0,0653	-0,0692	0,4058**	0,5761**	0,3302**	0,5425**
SCIIV(c)	-0,1967	-0,0360	-0,1291	-0,1183	-0,2246*	-0,1522	0,0812	0,2632*	0,2800*	0,1952
SCIV(d)	-0,1121	-0,1075	+0,0760	-0,0560	-0,1569	-0,0203	-0,2570*	-0,0378	0,3484**	-0,0848

	MATHSIV	MATHSV	JCIJC	SCIIV	SCIV
MATHSIV	-				
MATHSV	0,2476**	-			
SCIJC	0,2669*	0,0188	-		
SCIIV	0,2807*	0,0699	0,4136**	-	
SCIV	0,0296	0,2288*	0,0975	0,3070**	-

a) N = 80
b) N = 60
c) N = 57
d) N = 53

* Indicates significance at 0,05 level
** Indicates significance at 0,01 level.

The intercorrelation matrix between the ART-SL and the Mental Alertness-HL, Mathematics-Diagnostic 1 and the Calculation Test are all significant at the one percent level. Many of the items of the Mental Alertness-HL require number manipulations. The correlation with Verbal Comprehension is significant at the five percent level and there is no correlation with Reading Comprehension. This evidence suggests that the ART-SL is measuring in a similar domain for Blacks and Whites, viz. reasoning ability in a numerical context.

There appears to be no correlation between the predictors and the criteria. Given that the ART-SL has consistently shown itself to measure successfully in the arithmetical reasoning domain, one must look for an explanation of the lack of correlation in the criteria. One possible explanation is that Black education places emphasis on rote learning. It has been shown in two earlier studies (Sample 1 and Sample 7) that neither the ART-SL nor the ART-HL predict successfully under these circumstances. This does not mean that the test should not be used to select Blacks. To the contrary, the test will be more useful than school marks in predicting success for jobs or courses which demand conceptual and arithmetical ability. In Sample 8 the ART-SL was shown to be the most successful predictor of pre-Technikon training results.

One must also take cognisance of the difficult circumstances under which many Black students obtain their schooling. Often factors other than ability determine which students are successful. Such factors are inadequate study facilities, overcrowding in the school, lack of finance to continue studying etc.

5.3 Validation of ET-HL

Apart from the three studies quoted above in which ET-HL was applied (Samples 4, 5 and 7), the test was applied on three other occasions. On one of these occasions the test was applied to 154 rural Black school pupils in standards 9 and

10. The test proved to be very much too difficult for the pupils, most marks being little better than chance and the highest mark 11 (out of a possible 26). No further analysis was carried out on this group. The other two studies will be discussed in more detail.

5.3.1 Description of samples

5.3.1.1 Sample 11

The Estimation Test was administered to 204 White school pupils who requested vocational counselling from the NIPR. The sample consisted of 137 males and 67 females. Only 10 of the pupils were Afrikaans speaking, the rest being English speaking. All the pupils were in their matriculation year.

5.3.1.2 Sample 12

The Estimation Test-HL was administered to 188 applicants for jobs in which it was felt that a certain amount of accounting skill would be desirable eg. accountant clerks. In this sample the 26-item test was applied but only 19 items were scored. Items which were difficult and which involved tasks not usually expected of clerks were not scored. The test was administered by computer; there was a time limit on each item. The age range of the sample was 18 to 40 years. Education level was between 10 to 12 years. The sample comprised Afrikaans and English males and females.

5.3.2 Basic Statistics of ET-HL

The basic statistics for ET-HL obtained from the application of ET-HL to Samples 4,5 and 7 are presented in Table 21 together with the basic statistics for Samples 11 and 12. The number of subjects in each sample, mean, standard deviation, range and internal reliability (Kuder-Richardson formula 21, and Kuder-Richardson formula 21 with Tucker's correction for normal distribution) for the ET-HL based on the samples is given.

TABLE 21

SAMPLE SIZE, MEAN, STANDARD DEVIATION, OBTAINED RANGE AND RELIABILITY COEFFICIENTS FOR ET-HL

SAMPLE	N	$\overline{X}$	SD	OBTAINED RANGE MIN	MAX	KR	KR (CORRECTED)
4	72	17,28	3,81	9	25	0,625	0,677
5	107	12,98	4,05	4	22	0,627	0,673
7	180	14,99	4,41	4	26	0,701	0,746
11	204	11,67	4,47	1	25	0,705	0,743
12[a]	188	6,64	4, 5	0	18	0,78	0,835

(a) 19 item computerised ET-HL.

The test appears to be appropriate for all the groups. The test was slightly difficult for Sample 12 but the reliabilities are high despite the reduced length of the test. Subjects and Sample 4 found the test relatively easy. The reliabilities in Samples 4 and 5 reflect the highly selected nature of both samples.

5.3.3 **Validation studies based on ET-HL**

5.3.3.1 Sample 11

The pupils were given the Mental Alertness-HL, Pattern Relations (A15) and the Estimation Test-HL. A subtest of numerical items was drawn from the Mental Alertness-HL and used as a validation criterion. The intercorrelation matrix of these four variables is presented in Table 22.

TABLE 22

INTERCORRELATION MATRIX BETWEEN ET-HL, MA-HL, A15 AND CRITERION, SAMPLE 11, N = 204

	ET-HL	MA-HL	A15	CRITERION
ET-HL	-			
MA-HL	0,5320**	-		
A15	0,4700**	0,5870**	-	
CRITERION	0,4170**	0,6746**	0,3948**	-

* Indicates significance at 0,05 level

** Indicates significance at 0,01 level

A general intellectual ability component is required for effective performance on the ET-HL. This is shown by the correlations (significant at 0,01 level) of ET-HL with MA-HL and A15 and the slightly lower (though significant) correlation with the criterion. The criterion, being made up of only a subset of the MA-HL items, is appreciably less reliable than MA-HL itself. This probably accounts for the lower correlation of ET-HL with the criterion. An additional conclusion which can be made from these results is that logical reasoning ability seems to be an important component in the solution of ET-HL items.

5.3.3.2 Sample 12

Of 188 accountant clerks who completed the computerised version of ET-HL, 98 completed the Computation Test of the Intermediate Battery. The intercorrelation between the two tests was 0,60. If correction for attenuation is made this figure rises to 0,83. This is a slight over-estimate of the intercorrelation since in the calculation of this figure KR_{20} was used for the ET-HL, but KR_{21} (an underestimate of test reliability) was used for the Computation Test. This correlation is substantial. It is particularly remarkable in view of the following:

1. The Computation Test was performed in paper-and pencil format, whereas the ET-HL was done on computer.

2. In the ET-HL each item is timed and the subject is moved on to the next item (whether or not he has responded) once the time expires. In the Computation Test, only an overall time limit is applied.

3. The ET-HL requires the subject to round numbers and use quick strategies in order to estimate the value of numerical expressions. The Computation Test, on the other hand, requires the precise calculation of numerical problems.

The substantial correlation despite these differences indicates that the latent abilities measured by the two tests are quite similar, at least in the group to which the tests were applied.

6. Conclusions

These studies have shown the value of the ARTs and ET-HL in predicting success for certain groups of people on certain types of tasks. The ART-HL has shown itself to be appropriate for people who have achieved a "university quality" matriculation or who have a degree. Further research is required before it is recommended that this test be applied to racial groups other than Whites. The ART-SL is more appropriate for people who have ten to twelve years of schooling. The ET-HL has been successfully applied to people with ten or more years of schooling.

The studies have consistently shown similar patterns of intercorrelation between the ARTs and other tests, viz. high

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correlations with tests that measure logical ability in a number context, lower correlations with tests of general intellectual functioning and low or nonsignificant correlations with spatial or verbal ability tests. The ARTs should prove to be useful in selection and vocational guidance for fields such as mathematics, physics, chemistry, electronics, computer science and engineering. They are not useful in predicting success in disciplines which do not place both conceptual and quantitative demands. In accountancy, for instance conceptual demands are relatively low, although the numerical demands are high. ART is likely to be a less succesful predictor in such cases, than tests like ET-HL. The ART-SL may prove to be particularly useful in selecting Blacks where school results may be more a reflection of the education system than ability in the quantitative-cognitive domain.

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