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The SHL Verify™ Range of Ability Tests

> Technical Manual

test with confidence

Version 2.0 Oct 2007

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> Technical Manual

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Acknowledgements

Many people were involved in the development of the SHL Verify Range of Ability Tests. We would like to thank all the staff in the SHL Science & Innovation team whose dedication and hard work from November 2003 on the psychometric programmes now supporting SHL's test development processes made the SHL Verify Range of Ability Tests possible.

As with any major product development programme, its success depends on a team effort. Space prohibits mention of all of those involved in the programme, but your hard work and long hours have realised what we believe to be an innovation in employment testing that will realise significant benefits for organisations and candidates in delivering a better fit of people to the world of work.

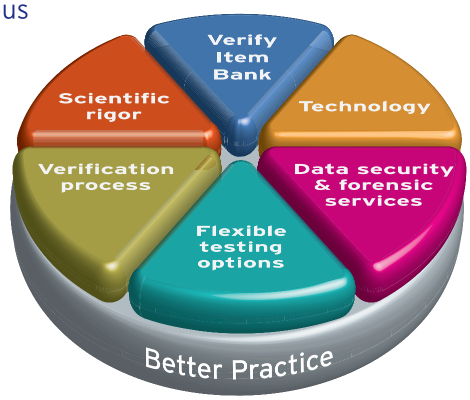
Introduction

This manual describes the development of the SHL Verify Range of Ability Tests that form a key part of the SHL Verify solution to unsupervised online testing. This manual provides key details of the psychometric properties of these tests as well as the methods used and the logic behind the SHL Verify Range. It is one of several documents supporting the use of the SHL Verify Range that also include the associated **User Manual**, the **Better Practice for Unsupervised Testing white paper** and the **Better Practice Guide for Unsupervised Online Assessment,** which sets out the philosophy behind the SHL Verify solution, and the key steps that users should follow to secure the validity of ability tests administered online.

This introduction covers an overview of the SHL Verify solution and the key features of the SHL Verify Range including the range of tests and comparison groups as well as the reports provided through the SHL Verify Range.

The issue of cheating, piracy and Internet testing

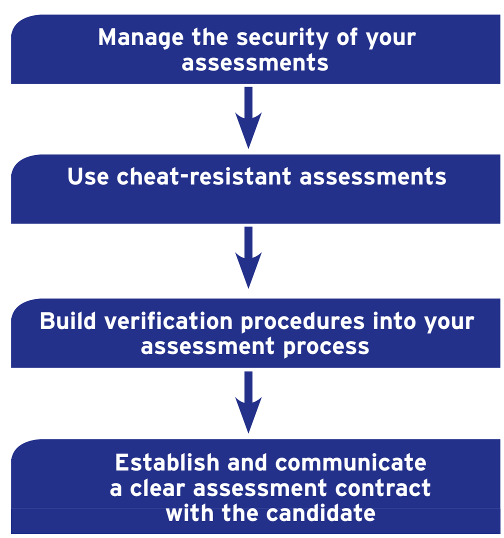
As evidenced in the debate described in the paper by Tippins, Beaty, Drasgow, Gibson, Pearlman, Segall and Shepherd (2006), the biggest concerns with unsupervised Internet testing are with cheating and the actions of content pirates to support cheating. Cheating represents a conscious effort to achieve an inflated score on an assessment and, thereby, to improve the chances of successfully achieving an objective such as a job offer (Cizek, 1999). On ability tests, it represents a false score on the test that is significantly higher than the person's true ability. Cheating is inherently unfair in reducing the opportunities of those candidates who have taken the assessment honestly and whose scores are above the score cut-off(s) used for decision making but below those obtained by cheats.



Organisations are moving increasingly to the Internet for administration of tests, and this raises the issue of potential cheating where such tests are not supervised by an administrator who is physically present.

What is the SHL Verify solution to online ability testing?

A key part of the solution offered by SHL Verify is the use of unsupervised but cheat-resistant tests from which an accurate score can be obtained, and which are followed up by psychometric verification tests that are used to validate the first score.



The SHL Verify solution brings these components together in a systematic series of steps for better practice in online assessment (see Burke, 2006, for more details).

The key steps proposed by SHL's better practice are summarised on the right. A key step is the use of cheat- resistant assessments, and the SHL Verify Ability Tests have been designed to meet that requirement.

Another key step is the use of verification to provide checks on the validity of candidates' scores. The SHL Verify Verification Tests have been designed to serve this purpose.

What is the SHL Verify Range of Ability Tests?

The SHL Verify Range of Ability Tests comprises reasoning tests designed for administration online and to be resistant to cheating and piracy of content. SHL Verify consists of two stages:

1. **The SHL Verify Ability Test (VAT)** is intended for administration online and unsupervised. These tests are drawn from an item bank that provides different but equivalent tests administered randomly to candidates. This feature has been designed to minimise the ability of candidates to access answers to tests, and to reduce the ability of candidates to collude through the exchange of answers to items.

2. **The SHL Verify Verification Test (VVT)** is a short test that has been designed to offer an equivalent and supervised follow-up assessment to the VAT. This test checks the consistency of scores from the first unsupervised online test and flags inconsistent scores for follow up.

Stage 1	→	Stage 2
Verify Ability Test Accurate Verbal / Numerical / Inductive reasoning test designed to be administered online and unsupervised Ability Report output provides the score that is then verified through the Verification Test	→	**Verification Test** Verifies candidate performance on the Verify Ability Test Verification Report output - no additional score, just a simple Verified / Not Verified classification

What does the Verify Range Measure?

The Verify Range of Ability Tests currently comprises 3 individual measures of reasoning; Verbal, Numerical and Inductive Reasoning. The 3 tests can be administered either separately or in any combination driven by the requirements for an assessment.

Both the Verbal and Numerical tests are examples of deductive reasoning measures. Broadly speaking, this is the ability to work with problems that are bounded and where methods or rules to reach a solution have been previously established. Inductive reasoning extends the range of assessments available from the Verify range to include the ability to work with problems that are novel and that require individuals to work from first principles in order to reach a solution.

Test Overview

	Verify Ability Test	Verification Test
Verbal	30 items	18 items
	17-19 minutes*	11 minutes
Numerical	18 items	10 items
	17-25 minutes*	14-15 minutes*
Inductive	24 items	7 items
	25 minutes	7 minutes

* Verify offers tests at different job levels and the time for Verify tests varies depending on the level of the test used.

What is Verification?

Verification procedures are checks on the consistency of scores using verification tests and other information that support or question the validity of a candidate's test score(s). Background checks are used by many organisations to check the validity of résumés and CVs, and verification procedures follow similar principles in looking at several sources of data related to a test score to check its validity.

Verification is distinct from **authentication**, which is concerned with confirming the identity of the candidate. We recommend that all assessment processes specify and include one or more stages at which the candidate's identity is authenticated. Verification procedures are concerned with validating a candidate's score on an assessment. These include:

- The use of **psychometric verifications** such as the SHL Verify Verification Tests, which provide strong checks on the validity of scores by using equivalent content contained in short but accurate assessments.
- The use of **other assessments** to check the candidate's potential and fit to the role or job. Information from a reasoning test, a personality measure, assessment centre exercise and a well-structured interview can be used to contribute to an overall assessment of potential and fit. Assessments such as ability and personality measures administered unsupervised online would provide data on whether the candidate should be called forward for a second-stage assessment and, if they should, what areas need to be probed in more depth before an appointment decision can be made. Cross-referencing information from several assessments to focus on areas of inconsistency is another form of verification.
- The use of **other verifiable information** related to the assessment being verified. For example, if the assessment is measuring numerical reasoning, then information on the candidate's educational performance related to numerate subjects would be relevant and could be verified.

Suitability of the SHL Verify Range for use in assessment

Cognitive or reasoning ability has been shown by a wide body of research to be the most consistent predictor of job performance (Schmidt and Hunter, 1998). The SHL Verify Range is relevant to assessment where the following are critical aspects of the job or role (these requirements are taken from the SHL Universal Competency Framework or UCF and further details on the UCF and its validity are available in Bartram, 2005):

UCF DIMENSION
Presenting & Communicating Information
Writing & Reporting
Applying Expertise & Technology
Analysing
Learning & Researching
Creating & Innovating
Formulating Strategies & Concepts

The Verify Ability Tests have been designed to operate at six levels from manager and graduate through to supervisory and operational roles.

The Verify Ability Tests have been developed to provide equivalent quality and levels of assessment to SHL's **Advanced Managerial Tests** (AMT), the **Management and Graduate Item Bank** (MGIB), the **Critical Reasoning Test Battery** (CRTB), the **Customer Contact Ability Series** (CCAS) and the verbal and numerical reasoning tests contained in the **Personnel Test Battery** (PTB).

Tailoring of the tests to meet user requirements has also been facilitated by the availability of Comparison Groups (norms) covering four industry sectors plus a general composite at each of the job levels. In total, the SHL Verify Range offers 70 comparison groups (test types by job levels by industry sectors) to support the valid interpretation of scores. These are summarised in the table overleaf. Please note that work is ongoing to update the range of comparison groups available through Verify and we will provide updates as the range of comparison groups is extended.

	Verbal	Numerical	Inductive
Manager / Professional	✓	✓	✓
Graduate	✓	✓	✓
Junior Manager	✓	✓	
Senior Customer Contact	✓	✓	
Junior Customer Contact	✓	✓	
Administrator	✓	✓	

How do I access the results from SHL Ability Tests?

The SHL Verify Range provides two types of report for users:

1. **The Verify Ability Test Report** which is a computer-generated report providing a candidate's score on the VAT using the comparison group selected by the user. The user has the choice of using only one, two or all three tests currently available. The VAT report caters for each of these three choices. An example of a VAT report generated for a candidate who has completed a verbal and a numerical test is shown below:


Verify
test with confidence
Ability Test Report
Name: **Sample Candidate**
Date: 09 June 2006
shl
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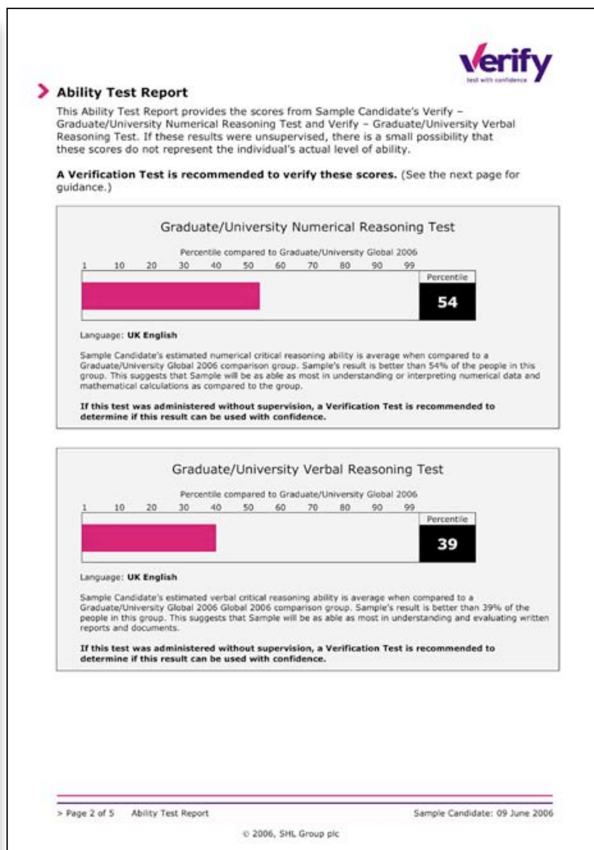
Verify
test with confidence

Ability Test Report

This Ability Test Report provides the scores from Sample Candidate's Verify – Graduate/University Numerical Reasoning Test and Verify – Graduate/University Verbal Reasoning Test. If these results were unsupervised, there is a small possibility that these scores do not represent the individual's actual level of ability.

A Verification Test is recommended to verify these scores. (See the next page for guidance.)

Graduate/University Numerical Reasoning Test

Percentile compared to Graduate/University Global 2006

1 10 20 30 40 50 60 70 80 90 99

Percentile 54

Language: **UK English**

Sample Candidate's estimated numerical critical reasoning ability is average when compared to a Graduate/University Global 2006 comparison group. Sample's result is better than 54% of the people in this group. This suggests that Sample will be as able as most in understanding or interpreting numerical data and mathematical calculations as compared to the group.

If this test was administered without supervision, a Verification Test is recommended to determine if this result can be used with confidence.

Graduate/University Verbal Reasoning Test

Percentile compared to Graduate/University Global 2006

1 10 20 30 40 50 60 70 80 90 99

Percentile 39

Language: **UK English**

Sample Candidate's estimated verbal critical reasoning ability is average when compared to a Graduate/University Global 2006 Global 2006 comparison group. Sample's result is better than 39% of the people in this group. This suggests that Sample will be as able as most in understanding and evaluating written reports and documents.

If this test was administered without supervision, a Verification Test is recommended to determine if this result can be used with confidence.

> Page 2 of 5 Ability Test Report Sample Candidate: 09 June 2006

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2. The Verification Report is a computer-generated report that provides the results of the psychometric verification following the administration of a VVT. This is the report that indicates whether the candidate's scores from the VAT are consistent and are likely to be a valid indicator of the candidate's ability, or whether the candidate's score is aberrant and, therefore, the validity of the VAT score is questionable and should be verified further. An example of this report generated for a candidate who has completed a verbal and a numerical test is shown below:


verify
test with confidence

Verification Report

Name: **Sample Candidate**
Date: 09 June 2006

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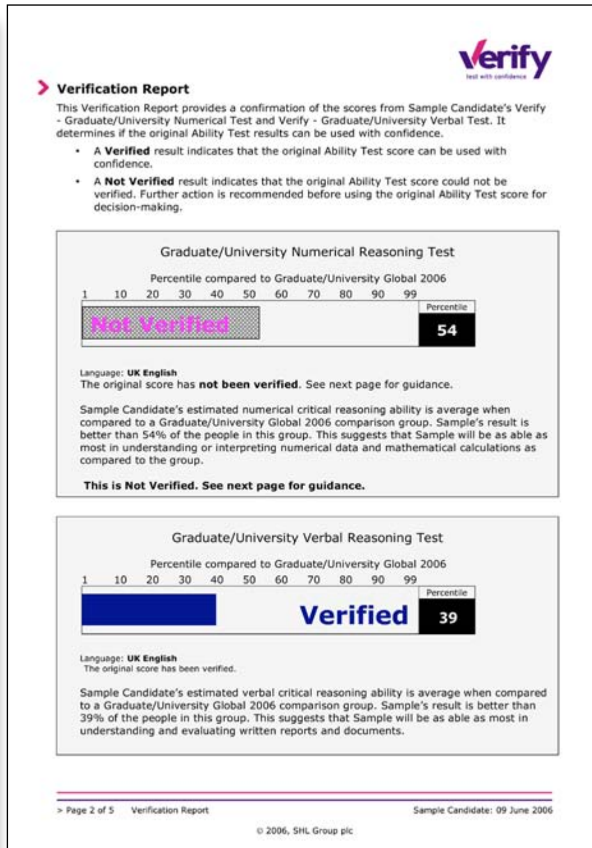
verify
test with confidence

Verification Report

This Verification Report provides a confirmation of the scores from Sample Candidate's Verify - Graduate/University Numerical Test and Verify - Graduate/University Verbal Test. It determines if the original Ability Test results can be used with confidence.

- A **Verified** result indicates that the original Ability Test score can be used with confidence.
- A **Not Verified** result indicates that the original Ability Test score could not be verified. Further action is recommended before using the original Ability Test score for decision-making.

Graduate/University Numerical Reasoning Test

Percentile compared to Graduate/University Global 2006

1 10 20 30 40 50 60 70 80 90 99

Not Verified — Percentile 54

Language: **UK English**
The original score has **not been verified**. See next page for guidance.

Sample Candidate's estimated numerical critical reasoning ability is average when compared to a Graduate/University Global 2006 comparison group. Sample's result is better than 54% of the people in this group. This suggests that Sample will be as able as most in understanding or interpreting numerical data and mathematical calculations as compared to the group.

This is Not Verified. See next page for guidance.

Graduate/University Verbal Reasoning Test

Percentile compared to Graduate/University Global 2006

1 10 20 30 40 50 60 70 80 90 99

Verified — Percentile 39

Language: **UK English**
The original score has been verified.

Sample Candidate's estimated verbal critical reasoning ability is average when compared to a Graduate/University Global 2006 comparison group. Sample's result is better than 39% of the people in this group. This suggests that Sample will be as able as most in understanding and evaluating written reports and documents.

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What will I find in the rest of this manual?

The remaining sections of this manual provide the reader with the following information:

- The development of the item banks that support the SHL Verify Range
- The psychometric properties of the SHL Verify Ability Tests and Verify Verification Tests
- Descriptions of the comparison groups used to interpret SHL Verify Ability Test Scores
- The criterion validity of the Verification Ability Test scores
- How psychometric verification preserves the validity of the Verify Ability Test scores
- Comparisons of Verify Ability Test scores by sex, ethnicity and age

The development of the SHL Verify item bank

In contrast to traditional ability tests, the SHL Verify Range uses an item bank to construct tests on demand for candidates. The SHL Verify item bank is a database that contains individual items and their psychometric properties. Using Item Response Theory (IRT) as explained in more detail below, tests are constructed using a series of rules such as length (number of items), total test time and the accuracy required of the test. This enables different but equivalent tests to be randomly assigned to candidates thereby managing cheating and piracy. This section explains the key principles and methods used to develop the SHL Verify item banks.

Key concepts in IRT

Traditional methods of constructing tests known as Classical Test Theory or CTT suffer from a number of limitations, amongst the most significant of which are:

- That the estimates of the psychometric properties of an item are fixed in relation to other items in the test.
- That the estimates of item properties are fixed in relation to the samples of people from whom psychometric data were gathered.

As such, data gathered from CTT limits the development of item banking and the use of randomised testing. IRT, in contrast, does not suffer from these limitations as estimates of the properties of items are independent of other items used in a trial form or an operational test. Furthermore, properties of items estimated through IRT are also independent of the samples from which item data are gathered. A third property of IRT models relevant to randomised testing is that the estimate of a candidate's ability or theta score, θ, is independent of any particular set of items used to estimate it.

These advantages of IRT do come with the key caveats that the samples used to estimate item and test properties are sufficiently large to provide accurate estimates, that those samples are not substantially biased in some systematic way, and that trial and operational forms of tests contain sufficient good quality items to enable an accurate estimate of a person's theta to be obtained (see Hambleton, Swaminathan and Roger, 1991, for an introduction and more detailed explanation of these features of IRT models). The next page provides a summary and comparison of the key parameters used in both CTT and IRT to describe the psychometric properties of items and tests.

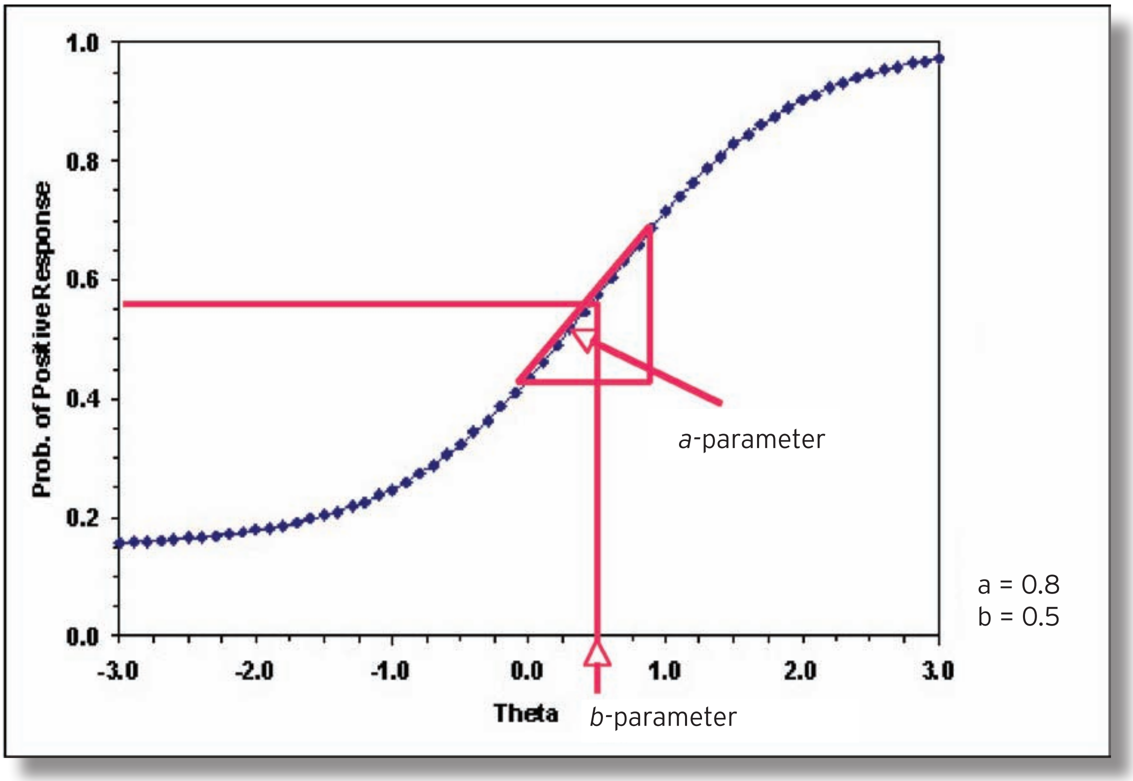
IRT models vary in the assumptions they make about an item and what it measures. As described in the next table, IRT models include four key parameters: the theta or θ metric that describes the level of ability and difficulty of items; the *a*-parameter that describes how well an item discriminates between lower and higher abilities; the *b*-parameter that describes the level of ability at which the item provides maximum discrimination; the *c*-parameter that describes the extent to which the item is subject to guessing the correct answer.

CTT Parameter	Analogous IRT Parameter
Item difficulty (or facility) index or *p* = the proportion of a sample who answer questions correctly where 1-*p* is the proportion answering incorrectly	The *b*-parameter = the point on the ability or theta scale, θ, where the probability of getting an item correct is 50%
Item discrimination or item partial = the correlation between getting the item correct and the total score on all other items	The *a*-parameter = the slope of the item characteristic curve at the *b*-parameter for the item
Correction for guessing as applied to number correct score and based on 1/n where n is the number of response alternatives	The *c*-parameter = the effect of getting the item correct through guessing
Number correct score = an estimate of ability taken from CTT based tests	Theta or θ = the score obtained for a person based on the responses to items and the item parameters
Reliability = an index ranging from -1 through zero to +1 indicating the extent to which items in a test or scale are functioning in a consistent way in estimating a trait	Information Function $I(\theta)$ = a scale indicating the information value for an item at specific values of θ Test Information Function (TIF) = the sum of information functions across items at key points of a θ range showing where estimates of θ are likely to be accurate and where those estimates are subject to greater error of measurement
Standard Error of Measurement (SEM) = an index of the range of number correct or transformed score points within which a person's true score is estimated to lie	Standard Error (θ) = the error associated with the point on the θ scale at which an ability or trait score is estimated for an individual

The following represent the three most widely used IRT models:

- 1-parameter or Rasch models assume that all items are equally discriminating or have equivalent *a*-parameters, but items are assumed to vary in terms of difficulty or the *b*-parameter. The major assumption here is that all items are equivalent in their representation of the construct or trait being measured.
- 2-parameter models assume that items vary not only in terms of difficulty (or the *b*-parameter) but also in terms of discrimination (the *a*-parameter).
- 3-parameter models assume that items vary in terms of the *a* and *b*-parameters, and also in a third parameter, *c*, which represents the likelihood of guessing the answer correctly on an item.

The properties of an item are described in IRT through Item Characteristic Curves or ICCs. These describe where on the ability metric or theta an item is located in terms of difficulty (the *b*-parameter) and over what range of ability the item discriminates (the *a*-parameter). An example of a 2-parameter ICC for an item is shown in the figure below.



The expected probability of answering an item correctly (Prob. of Positive Response) is shown as the Y-axis, while the X-axis represents the theta, θ, scale or the level of ability. The function plotted in blue is the ICC for this item showing how the probability of a correct answer varies by level of ability or θ. The difficulty or *b*-parameter for this item lies at about a theta of 0.5 and is the point on the theta scale that corresponds with the expected probability of a correct answer being 50%. The *a*-parameter is obtained by determining the slope of the ICC at this point.

Applying IRT to the construction of SHL Verify item banks

The fit of 1, 2 and 3-parameter models to SHL Verify ability items were tested early in the SHL Verify programme with a sample of almost 9,000 candidates. As expected, the fit of a 1 parameter model to items was poor, but the expected gain from moving from a 2 to a 3-parameter model was not found to be substantial, and for the majority of items evaluated (approaching 90%) no gain was found from moving to a 3-parameter model. Accordingly, a 2-parameter model was selected and used for the calibration of verbal and numerical item banks as generated for the SHL Verify Range.

The item development programme supporting the SHL Verify Range of Ability Tests extended over 36 months during which items were trialled using a linked item design and with a total of 16,132 participants. Demographic details of the sample used to evaluate and calibrate SHL Verify items are provided in the sections in this manual that describe the SHL Verify comparison groups and the relationships between SHL Verify Ability Test scores and sex, ethnicity and age.

Items were screened for acceptance into the item bank using the following procedure:

- A sensitivity review by an independent group of SHL consultants experienced in equal opportunities was used to identify and screen out items that might be inappropriate or give offence to a minority group. This was conducted prior to item trials.
- Once trial data was obtained, *a*-parameters were reviewed with items exhibiting low *a*-parameters being rejected.
- Review of *b*-parameters with items exhibiting extreme values (substantially less than -3 or greater than +3) being rejected.
- Review of item response times (time to complete the item) with items exhibiting large response times (e.g. 2 minutes) being rejected.
- Item distractors (alternate and incorrect answer options presented with the item) were also reviewed with items being rejected where distractors correlated positively with item-total scores (i.e. indicators of multiple correct answers to the item) or where the responses across distractors were uneven (the latter analysis being conditional on the difficulty of the item).

Items surviving the above procedure were subjected to a final review in terms of *a* and *b*-parameters as well as content and context coverage (i.e. that the item bank gave a reasonable coverage across different work settings and job types). This final review also sought to provide a balance across the different response options for different item types. That is, the spread of correct answers for verbal items avoided, say, the answer A dominating over B and C correct answers across items in the SHL Verify item bank, and that the spread of correct answers was approximately even for A, B, C, D and E options across numerical and Inductive Reasoning items.

The psychometric properties of scores obtained from the SHL Verify Range of Ability Tests

This section provides details of the accuracy of the Verify Ability scores. The operational length of any test, and therefore its accuracy, is principally defined by two factors: the quality of the items and the time considered practical for administration of a test.

In recent years, SHL has pursued a programme to improve the quality of items in a focused effort to reduce the time required for test administration while still obtaining an accurate estimate of a candidate's ability. Reducing the length of a test also provides significant benefits when using randomised tests by minimising the exposure of items contained in the item bank

Randomised online ability testing

A key innovation enabled by IRT models is that a candidate's ability can be estimated using different combinations of items. This is dependent on the items measuring the same construct and being calibrated on a common scale. The scale used to calibrate items and to provide ability estimates is the theta (or θ) scale which is explained in more detail below.

SHL Verify uses the advantages offered by IRT to provide a cheat resistant method of administering ability tests online and unsupervised. Given that a candidate's ability can be estimated using different combinations of items from a calibrated item bank, when different candidates register for a Verify Ability Test they receive a different but equivalent test. As such, the opportunity for candidates to collude by exchanging answers is minimised, as is the opportunity to access and memorise the answers to items given the size of the SHL Verify item bank. This cheat-resistant feature is then strengthened by the use of follow-up Verification Tests which are described in more detail in a later section of this manual.

Scoring of SHL Verify Ability Tests

Ability tests are traditionally scored using the number correct model which is the simple sum of correct answers to the items contained in a test. IRT uses the θ metric which can be interpreted as a standard normal deviate or Z score with a mean of 0 and a standard deviation of 1. As such, a θ of -1 would indicate someone scoring as well as or higher than the lowest 16% of candidates, a θ of 0 would indicate that a candidate has scored as well as 50% of candidates, and a θ of +1 would place a candidate in the top 16% of scores.

θ is obtained through an iterative process which essentially operates, for 2-parameter models, as follows:

- A set of items for which a and b values are known are administered to the candidate.
- The candidate's right and wrong responses to the items are obtained.
- An initial estimate of the candidate's θ is chosen (there are various procedures for making this choice).
- Based on the initial θ used and knowledge of each item's properties, the expected probability of getting the item correct is calculated.
- The difference between the candidate answering an item correctly and the probability expected of the candidate answering the item correctly, given the initial theta value, is calculated.
- The sum of these differences across items is standardised, and this standardised difference is added to the initial θ estimate (negative differences reducing the estimated theta and positive differences increasing it).
- If the differences are non-trivial, then the new θ estimate obtained from the previous step is used to start the above cycle again.
- This process is repeated until the difference between the value of θ at the start of a cycle and the value obtained at the end of a cycle is negligible.

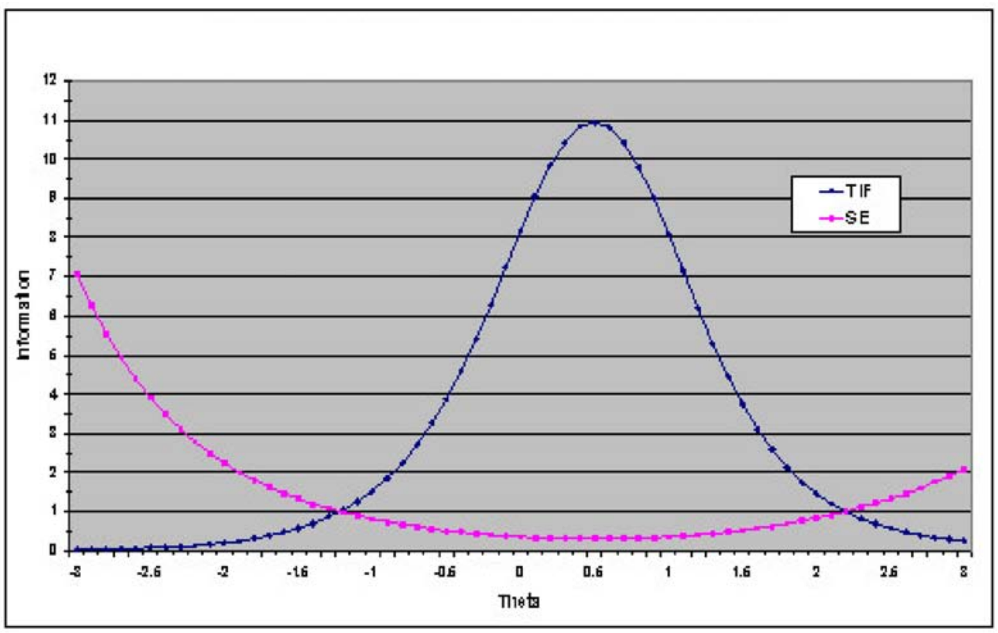
See Baker (2001) for a more detailed account of theta scoring with worked examples. This approach to scoring is suited to the randomised testing approach where candidates receive different combinations of items. As all the items are calibrated to the same metric, then this process also allows scores on different combinations of items to be directly compared and treated as from the same underlying distribution of ability scores.

Accuracy and consistency of SHL Verify Ability Test scores

The information provided by an item and a test is indexed in IRT using the Information Function or I(θ). The Information Function for an item is obtained by combining the expected probabilities of answering an item correctly and incorrectly at each point on the theta scale, weighted by the *a*-parameter (discrimination) of the item. I(θ)'s for items in a test can be summed to provide the Test Information Function. The TIF defines the range on the theta distribution within which a test provides maximum information on a candidate's ability. This, then, tells us the range of ability or theta across which the test functions effectively and provides accurate score information.

Score accuracy is indexed in IRT by the Standard Error of θ or SE(θ), which is given by $1/[I(\theta)]^{1/2}$. For those familiar with CTT indices, SE(θ) functions in a similar way to the Standard Error of measurement or SEM described in more detail below. However, while the SEM in CTT is a constant across the score range, SE(θ) is not and varies dependent on the properties of the items contained in a test and the range of θ under consideration.

The following figure provides an example of a TIF and SE(θ) for a hypothetical test. As can be seen, TIF reaches a maximum value at around 0.5 to 0.6 theta. SE(θ) reaches a minimum at this point on the theta scale and increases substantially from -2 theta and below.



The analogous indices to the TIF and SE(θ) in CTT are the test score reliability and the SEM as mentioned earlier. Using CTT models, reliability can be estimated in different ways depending on the question being asked of the quality of test scores:

- To answer the question of how a test score is affected by the quality of the items in a test, reliability can be estimated using the Internal Consistency Coefficient that reports the proportion of variation in scores that can be attributed to consistency in the measurement properties of the items in the test.

- To answer the question of how a test score is affected by variation in the measurement qualities of different versions of a test (i.e. which version is administered to an applicant), reliability can be estimated using the Alternate Forms Coefficient which reports the percentage of variation in scores that can be attributed to consistent measurement across test versions.
- To answer the question of how consistent scores are over time, then reliability can be estimated by the Test-retest or Stability Coefficient which reports the proportion of variation in applicants' rankings on test scores across two or more administrations at different times.

From the reliability estimated for a score, the standard error of measurement or SEM can be calculated using the formula $(1-r_{xx})^{1/2}$ x SD, where r_{xx} represents the estimated reliability of the score and SD represents the standard deviation of scores. The SEM is used to define a range within which a person's true score is likely to lie. For example, if the reliability of a test is estimated to be 0.8 for a test with an SD of 5, then the SEM for a score obtained from that test is given by $(1-0.8)^{1/2}$ x 5 or 2.24. If a person were to obtain a score of 10 on the test, then there would be a 68% probability that the person's true score lies between a score of 8 (nearest whole score to 7.76 and 1 SEM below the observed score) and a score of 12 (nearest whole score to 12.24 and 1 SEM above the observed score).

As indicated by the formula for the SEM, reliability coefficients can be interpreted as the proportion of variation in test scores attributable to true measurement rather than errors arising from poor test construction, poor administration and other factors influencing the quality of an assessment. A reliability of 0.8 indicates that 80% of the variation in test scores is attributable to true measurement.

Both CTT and IRT indices of test score quality were used to evaluate the consistency in quality of the randomised Verify Ability Tests. The procedures used were as follows:

- Based on knowledge of the properties of existing SHL test batteries, θ ranges were defined as those typifying candidates at the managerial and graduate level, and candidates at the supervisory and operative level.
- Using those θ ranges, 100 typical Verify Ability Tests were generated for each type of test and at each job level, giving four sets of 100 or a total of 400 verbal and numerical tests for evaluation. A similar procedure was applied to Inductive Reasoning tests at the managerial and graduate level.
- The internal consistency of each test was estimated using procedures similar to those described in duToit (2003).
- The variability of reliabilities across each group of tests was then measured using the median and inter quartile range. The results of this analysis are presented in the later sections of this manual describing the psychometric properties of each Verify test. For the Verify Ability Tests, reliability estimates ranges from 0.77 to 0.84.

Scales for reporting ability test scores

As with any test or questionnaire, scores on the Verify Ability Tests are interpreted by converting theta scores to standard scales. These include:

- **Percentiles**. A percentile score is a score below which a certain percentage of the members in the comparison group fall. For example, the 90th percentile is the point below which 90% of the members of the comparison group score. Percentiles are an example of ordinal measurement, which means that they provide an indication of ranking by test score.

  Percentiles have the advantage of being easily obtained and understood. However, they suffer the disadvantage that they are not equal units of measurement. Accordingly, percentiles should not be averaged.

- **Standardised Score Scales**. To overcome problems implicit within rank order scales such as percentiles (i.e. measurement scales that do not have equal units of measurement) various types of standardised scales have been developed. The following are among the most common used in employment settings.

  The standard score or Z-score is based on the mean and standard deviation. It indicates how many standard deviations a score is above or below the mean. Usually when standard scores are used they are interpreted in relation to the normal distribution curve. One advantage of using the normal distribution as a basis for comparison groups is that the standard deviation has a precise relationship with the area under the curve. For example, one standard deviation above and below the arithmetic mean includes 68% of the scores. The theta score obtained from the Verify Ability Tests can be treated as a Z-score.

  In the SHL Verify Ability Test Report, two transformed standard score scales are provided: **T-scores** and the **Sten scale**. T-scores are a transformation of the Z-score based on a mean of 50 and a standard deviation of 10. They represent equal units of measurement and therefore may be manipulated mathematically (e.g. summed or averaged).

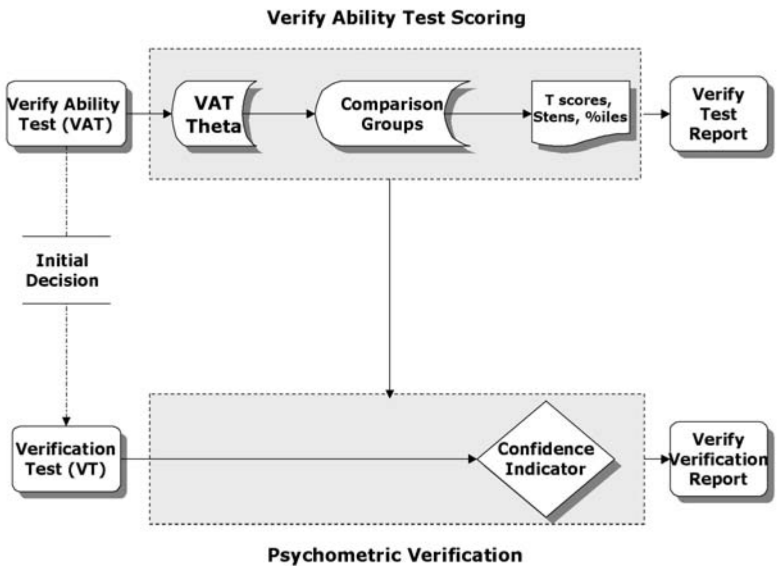
  Sten is an abbreviation of standard ten and divides the score range into ten units. It is based on a mean of 5.5 and a standard deviation of 2. Sten scores are taken to the nearest whole number with a minimum value of 1 and a maximum value of 10.

How psychometric verification preserves the validity of the Verify Ability Test scores

This section describes how the SHL Verify Range of Ability Tests incorporates psychometric verification in the testing process, and the evidence supporting its accuracy in detecting cheating and correcting for it.

The SHL Verify process of psychometric verification

The SHL Verify testing process is described in the figure below. It includes an unsupervised ability test followed by a supervised verification test, both of which are delivered online. At a point prior to or at the point of administering the Verification Test, it is strongly recommended that the candidate's identity is authenticated. We recommend that authentication requires the candidate to provide identification by means of a legal document containing photographic identification. Examples would include a passport, national identification card or a driver's license containing a photograph.



The point at which the Verification Test is administered may be decided by the user depending on candidate volumes and when administration would be convenient in the assessment process. The following provides two example scenarios:

- In larger volume processes involving several stages and using a suitable cut-score on the Verify Ability Test score(s), candidates are sifted into call forward or reject groups. Verification Tests may be administered towards the end of the process when numbers of candidates have been reduced, and with the results of the Verification Test being made part of the conditions of employment offer.
- In smaller scale one-to-one assessments, verification might take place alongside other assessments used in an assessment or development centre, or at a subsequent stage such as final interview or feedback point.

Psychometric verification as offered by the SHL Verify Range compares the candidate's scores on the ability and verification tests to obtain a Confidence Indicator or CI. The CI checks the likelihood of the difference between the scores and, when that likelihood is small and statistically unlikely, flags the score(s) as not verified in the Verify Verification Report.

A score that has been flagged in this way is known as **aberrant** and an aberrant score **should not be interpreted as automatic evidence of cheating**. A not verified result may occur for various reasons such as the candidate's physical or psychological state when administered the Verification Test. An aberrant score does represent a score that has low validity, that merits investigation and that may lead to the need for a further Verify Ability Test administration.

Dealing with scores flagged as not verified

Before investigating an aberrant score, it is important to decide what the possible outcomes of that investigation and discussions with the candidate could be. One option would be to administer another Verify Ability Test in supervised conditions, and to use the score from that administration in place of the original score flagged as aberrant. It is possible that, when more than one Ability Test are used, one, two or three scores may be flagged as not verified. Where only one score has been flagged, then the user may administer another corresponding Verify Ability Test under supervised conditions to replace the score that has been flagged. Where two or all scores have been flagged, then the user is advised to administer corresponding Verify Ability Tests under supervised conditions.

Prior to a discussion of aberrant scores with a candidate, it is worthwhile looking at other available information that can help your understanding of why the scores may be so different. For example, is there information on the candidate's performance on related educational tests or exams? Is there information on the candidate's CV or résumé related to training and/or work experience of tasks involving general reasoning, numerical or verbal abilities? Are there other assessment data such as simulation scores involving verbal ability (such as in-trays, report writing, presentations, group discussions) or numerical ability (such as in-trays or other exercises involving the analysis and interpretation of numerical data)? Are there patterns in scores on other instruments such as the OPQ that are relevant such as the Evaluative Data Rational scales and Conceptual Reasoning?

Investigating an aberrant score should be undertaken with sensitivity. Discussions with a candidate whose score(s) have been flagged as not verified should begin by telling the candidate that the purpose of discussing their score results is to ensure that the assessment is accurate and valid, and to ensure that the candidate has a fair opportunity to proceed through the employment process.

When investigating a not verified score, the following possible reasons for aberrance should be explored:

- What was the candidate's physical condition at the time of the Verification Test administration? Was this significantly different to when the candidate sat the Verify Ability Test(s)?
- Were there any reasons why the candidate was unable to focus while taking the Verification Test such as distractions or interruptions?
- Did the candidate attempt all of the items in the Verification Test or only a few? Were there reasons such as physical or psychological factors that interfered with the candidate's ability to work through the Verification Test?
- Did the candidate make full use of the practice tests available prior to taking the Verify Ability Tests? Did they go to **www.shldirect.com** to take the practice tests available there? Keep in mind that, as the ability and verification tests are correlated 0.7 and above, then the candidate should have benefited from familiarity obtained from sitting the Verify Ability Test(s) when sitting the Verification Test (i.e. familiarity with the content, the interfaces and what is expected of them to answer the items).
- Why does the candidate think that performance on the two tests could be so different? Have they experienced this before when taking tests and/or exams in the past, or on previous ability tests taken during employment processes.

Notifying candidates at the start of the process that they are expected to take the tests honestly and that verification procedures will be used will reduce the incidence of cheating. An important aspect of test security is to establish a clear relationship with the candidate and to be clear about what the rules for assessment are that all candidates are expected to abide by. See Burke (2006) for a more detailed discussion of these issues.

How effective is the SHL Verify testing process in detecting cheats?

One of the possible reasons for an aberrant score flagged as not verified is that the first score was obtained through cheating, either by a proxy taking the test on behalf of the candidate or through collusion with others such as assistance from a coach. Cheating has the effect of inflating the candidate's test score which will be reported as substantially higher than the candidate's true ability.

A number of large-scale computer simulations were undertaken to evaluate how well the CI (Confidence Indicator) detects cheating. Simulations are a well-established method for testing models in psychometrics and the social sciences generally (see Mooney, 1997, for more details on the design and use of Monte Carlo simulations).

A variety of scenarios were tested using the simulations including percentage of the candidate population cheating, the type of cheating (by proxy or by collusion), the gain in scores from cheating (e.g. gains as much as 2 standard deviations in scores), as well impacts at different cut-score levels (e.g. 30th percentile versus 70th percentile). The basic structure of the simulations was as follows:

- A normal distribution of theta scores with a mean of 0 and a standard deviation of 1 was generated for a population of 10,000 candidates. These represent the true ability scores of the candidates.
- The IRT properties of SHL Verify items and tests were used to construct 100 tests assigned at random to candidates. These represent the reported ability levels of the candidates which will be inflated for scores achieved through cheating and when a candidate is assigned to the cheating group.
- A cheating condition was constructed such as cheating by proxy with cheats achieving a theta score of +2. These represent the inflated estimates of ability as would be reported by a compromised test.
- Random assignment of candidates to the non-cheating (honest) group and cheating groups based on a proportion of candidates cheating.
- Assignment to the cheating condition was also based on an assumed correlation between ability and the propensity to cheat of -0.3 (see Cizek, 1999, for information on research supporting this assumption). Thus, the probability of assignment to a cheating group was conditioned on the candidate's true ability.
- The results from the simulated cheating condition were then compared with results obtained from a matching simulation in which all candidates took the assessment honestly.

To evaluate the effect of cheating and the returns obtained from using the verification tests, a benefits ratio was constructed. This benefits ratio is based on the cross-classification as shown below of true and reported scores (although the example shows the 40th percentile as the basis for decisions, these ratios were computed for a range of cut-scores and the figure shows just one example of the cut-scores evaluated). The effect of cheating would be expected to increase the proportion of candidates classified as cell B (false selections) relative to the proportion of candidates classified as cell D (correct selections). The benefits ratio was defined as the ratio of D to B. For example, if the ratio of correct selections (D) to incorrect selections (B) for a sample of 120 is 100 : 20, then the benefits ratio (the measure of the benefit of using a test score) is 5 : 1. Benefits ratios were computed for both the Verify Ability Test stage and forthe verification stage.

		Candidate's True Ability	
		Less than 40th percentile	40th percentile or greater
Candidate's Reported Ability	Less than 40th percentile	A = correctly classified as candidates to be rejected	C = incorrectly classified as candidates to be rejected
	40th percentile or greater	B = incorrectly classified as candidates to be accepted	D = correctly classified as candidates to be accepted

Results across simulation scenarios were consistent and the following provides a typical set of results for a simulation of verbal scores where one-in-five candidates cheat by proxy, achieve a substantial gain in scores placing them well into the top 5% of scores on the first test, and where a cut-score of the 40th percentile is used to bring candidates forward to a subsequent stage or to reject candidates. The effects from cheating are compared to a matching simulation of honest test taking (i.e. no-one cheats).

Non-cheating (honest) condition

Candidate's Reported Ability \ Candidate's True Ability	Less than 40th percentile	40th percentile or greater
Less than 40th percentile	A=3,420 (34%)	C=655 (7%)
40th percentile or greater	B=633 (6%)	D=5,292 (53%)

Cheating (dishonest) condition

Candidate's Reported Ability \ Candidate's True Ability	Less than 40th percentile	40th percentile or greater
Less than 40th percentile	A=2,054 (20%)	C=480 (5%)
40th percentile or greater	B=1,989 (20%)	D=5,477 (55%)

Before discussing the honest versus cheating scenario comparisons, the reader may have noted two aspects of the results. First, there are a number of those with true ability above the 40th percentile who are rejected at the first stage of both scenarios (7% and 5%). This reflects the false negative rate that is a result of the test not having perfect reliability. The correct classification rates in both scenarios can be computed by the formula (A + D)/N, where N is 10,000, the total population size. In the honest condition, this is (3,420 + 5,292)/10,000 or 87%. In the cheating scenario, this is (2,054 + 5,477)/10,000 or 75%, which is substantially lower than the honest condition but still a reasonable correct classification rate. However, note that the incorrect classification rate almost doubles in the cheating scenario when compared to the honest test-taking scenario (25% as compared to 13%).

The second aspect is that the results of the two scenarios report different percentages for cells C and D, indicating variations across the two simulations. This is a consequence of the tests having high but not perfect reliability, and the fact that both simulations were run independently allowing the generation of true abilities and the assignment of simulated candidates to different Verify Verbal Ability Tests in each scenario to reflect variations in real world testing.

In the honest condition, the benefits ratio from using the ability score at the first stage is 5,292 : 633 or around 8. In other words, the return to the user is 8 correct decisions to every incorrect decision. The fact that the totals of those called forward, 633 + 5,292 or 5,925 (59% of candidates), is less than 6,000 (or 60%) again reflects the simple fact that Verify Ability Test scores are accurate but not perfectly reliable. In the cheating condition, we can see the inflation of Cell B as expected, and the benefits ratio has decreased to 5,477 : 1,989 or around 3.

The next step in the simulations was to administer the verification tests to those candidates brought forward in the honest and cheating conditions. The properties of the verification tests reported in this manual were used for this stage of the simulations. These results are summarised in the next set of tables which show that:

- In the non-cheating (honest) condition, 107 or 17% of the 633 candidates incorrectly brought forward from the first stage have their scores flagged as not verified. This compares to 265 of the 5,292 or 5% of those correctly brought forward who do not have their scores verified. The latter occurs because, while they are accurate and correlated with the ability scores, the Verification Tests are not perfectly reliable. The ratio of those with true ability above the 40th percentile who are called forward and whose scores are verified to those whose scores are verified but their true ability is less than the 40th percentile is 5,027 : 526 or around 10. This is a 25% increase over the benefits ratio of 8 obtained at the first stage.
- In contrast, for the cheating condition 1,465 or 74% of the 1,989 incorrectly brought forward from the first stage have their scores not verified. This compares to 509 or 9% of the 5,477 correctly brought forward and who do not have their scores verified (we will come back to this below). The benefits ratio at the verification stage in this cheating scenario is given by 4,968 : 524 or around 10, a three-fold increase on the benefits ratio of 3 obtained from the first stage where cheating has had a significant impact on the numbers getting through that stage.

Why do 9% of those who were correctly brought forward from the first stage have their scores not verified? The simulations allow us to know who in the population of candidates were cheats. As the propensity to cheat is negatively correlated with ability, this means that some of the candidates whose true ability is above the 40th percentile and did not need to cheat, did, nonetheless, cheat.

Non-cheating (honest) condition

Verification Test Result	First Stage Score: Incorrectly selected (B)	First Stage Score: Correctly selected (D)
Scores verified	526	5,027
Scores not verified	107	265

Cheating (dishonest) condition

Verification Test Result	First Stage Score: Incorrectly selected (B)	First Stage Score: Correctly selected (D)
Scores verified	524	4,968
Scores not verified	1,465	509

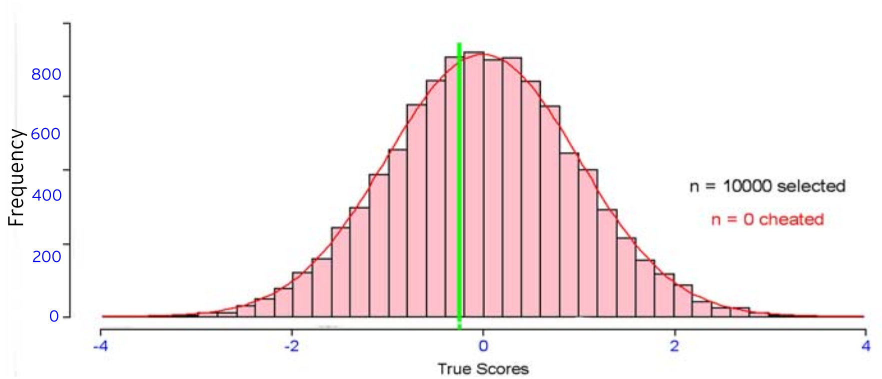
The following table shows the breakdown of not verified scores by cheats and non-cheats.

Breakdown of not verified scores	Incorrectly brought forward from first stage	Correctly brought forward from first stage
Non-cheats	50 (2%)	254 (13%)
Cheats	1,415 (72%)	255 (13%)

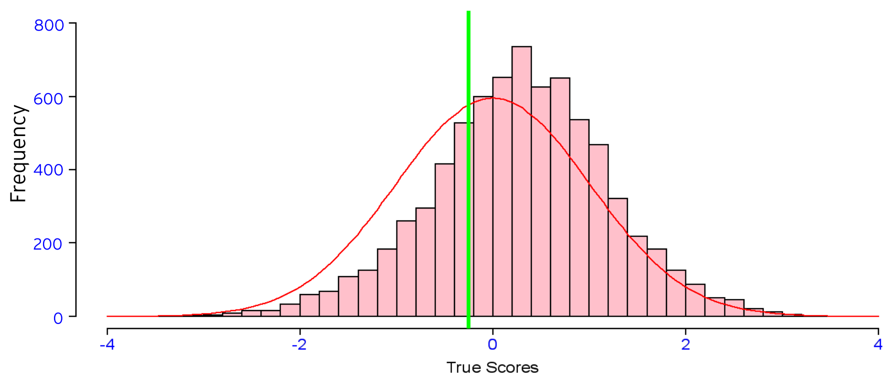
As we can see, around 50% of those who were correctly brought forward in the cheating scenario and flagged as not verified were, in fact, cheats (255 of the 509 with true abilities above the 40th percentile). Overall, 1,670 (1,415 + 255) or **85% of the 1,974 candidates not verified were cheats. Of the 1,989 brought forward in erro**r (their true abilities were below the 40th percentile), 1,465 or 74% were correctly identified through the verification test as not having a true ability above the cut-score used. Of these 1,465, 1,415 or **97% were cheats.**

In addition to offering detection of cheating, the verification stage also acts to correct errors at the first stage (as demonstrated by picking up false selections in the honest scenario described above). This correction can be seen by looking at the distributions of scores at each stage of the process for the cheating scenario. These are shown below.

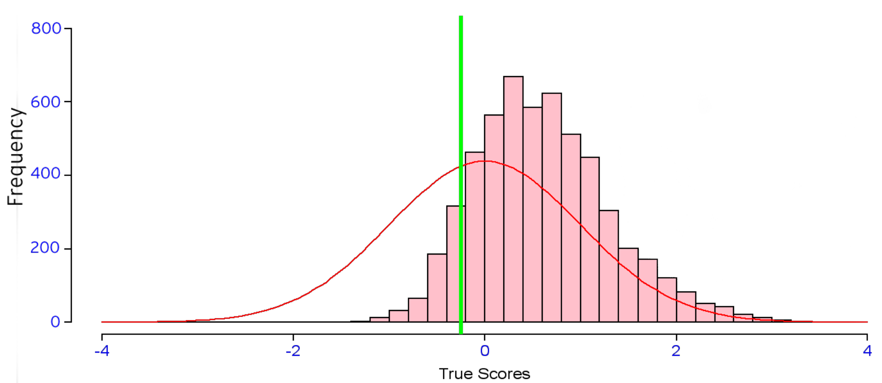
Distribution of true ability (θ) for the population of 10,000 (green vertical line shows 40th percentile cut-score)



Distribution of true ability (θ) for those passing the first stage



Distribution of true ability (θ) for those whose first stage score is verified



Summary

This section has described the process of psychometric verification offered by the SHL Verify Range of Ability Tests. As shown by the example taken from the extensive and large-scale simulations used to test the Verify process, psychometric verification is effective in identifying those brought forward from a first stage of assessment in error, and in identifying cheats. However, a score flagged as not verified in the Verify Verification Report should not be interpreted automatically as indicating cheating behaviour, and the possible reasons for an inconsistent and aberrant score should be investigated systematically and with sensitivity.

Technical details of the verbal and numerical Verify tests by general level

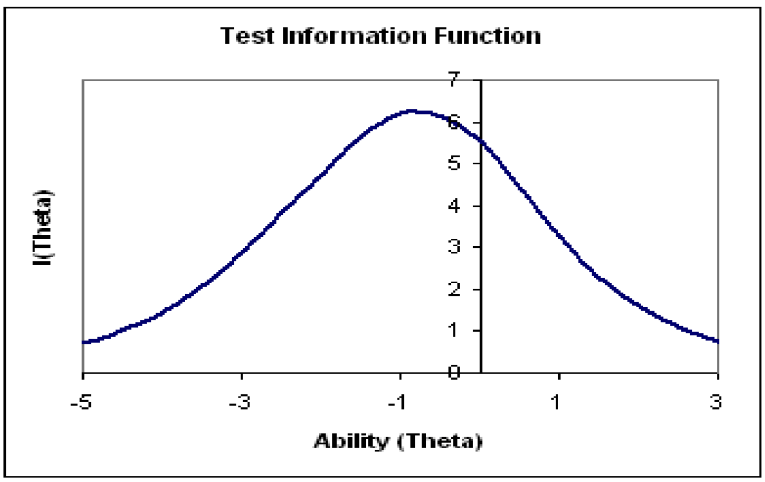
The Verify Range of Ability Tests currently comprises 3 individual measures of reasoning; Verbal, Numerical and Inductive Reasoning. The 3 tests can be administered either separately or in any combination, driven by the behaviours to be assessed.

Both the Verbal and Numerical tests are examples of deductive reasoning measures. Broadly speaking, this is the ability to work with problems that are bounded and where methods or rules to reach a solution have been previously established.

Verbal Test typifying the management and graduate levels

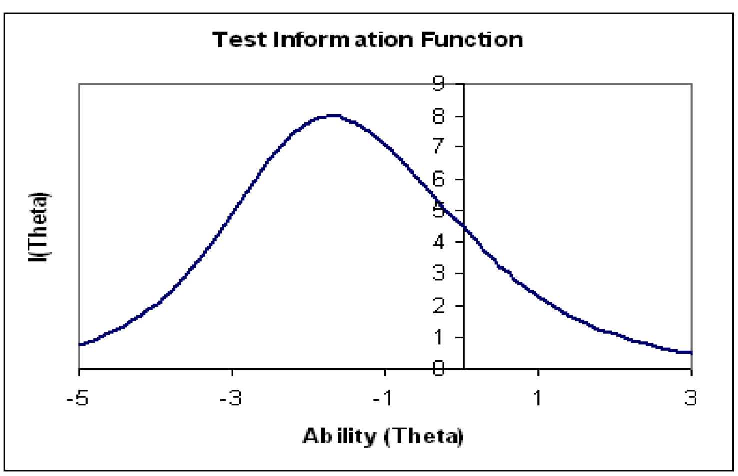
The figure below shows the θ range of the tests used to evaluate consistency in the quality of SHL Verify Verbal Ability Tests at this level. For a test operating with a CTT reliability of 0.8, the target TIF value is 5. This defines a θ range for effective functioning of tests typifying the upper end of difficulty in the SHL Verify verbal item bank as lying between θ's of -2 to +0.5.

For the 100 verbal tests generated in this range, the median reliability (internal consistency) was 0.81 with an inter quartile range of 0.79 to 0.82, indicating a high level of consistency within and across verbal tests.



Verbal Test typifying the supervisor and operational levels

The figure below shows the θ range covered by the tests used to evaluate consistency in the quality of SHL Verify Verbal Ability Tests at this level. The θ range of -3 to -0.8 defines the range for effective functioning of verbal ability tests at this level.

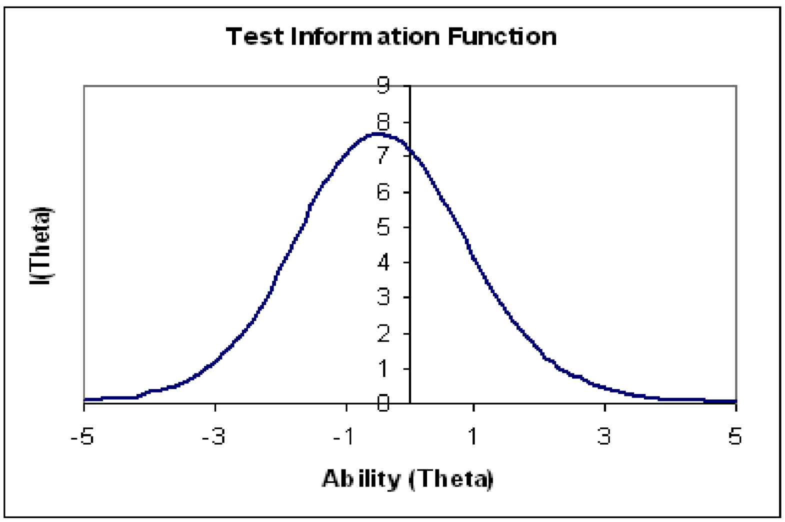


For the 100 verbal ability tests generated, the median reliability (internal consistency) was 0.78 and the inter quartile range was 0.77 to 0.80, indicating a high level of consistency within and across the tests generated.

Verify Numerical Reasoning is designed to measure a candidate's ability to make correct decisions or inferences from numerical or statistical data. The test is intended to measure the ability to work with numerical data in a realistic workplace context. Further details of the validation studies for Verify Numerical Reasoning can be found later on this manual.

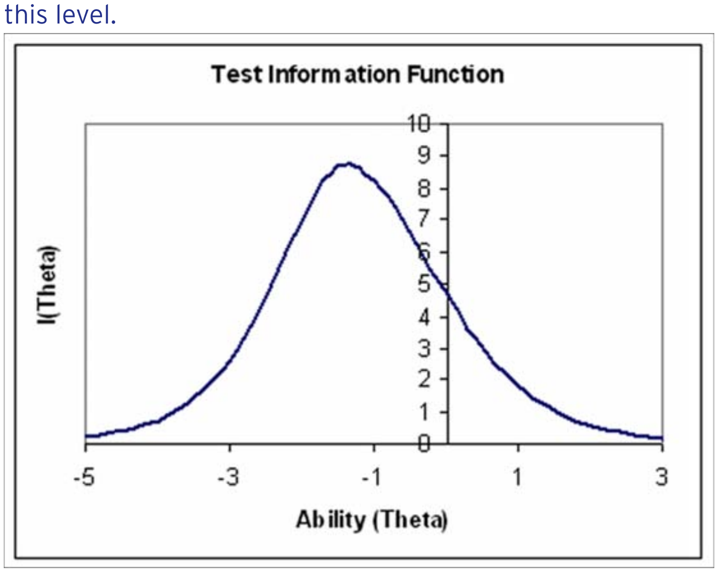
Numerical Test typifying the management and graduate levels

The next figure shows the θ range used to evaluate the SHL Verify Numerical Ability Tests at the manager and graduate levels. A theta range of between -1.5 and +1 was identified as defining effective functioning for numerical tests at these levels. For the 100 numerical tests generated in this range, the median reliability (internal consistency) was 0.83 and the inter quartile range was 0.81 to 0.84, again indicating a high level of consistency within and across typical numerical tests at this level.



Numerical Test typifying the supervisor and operational levels

The next figure shows the θ range used to evaluate the SHL Verify Numerical Ability Tests at the supervisor and operational levels for which a θ range from -2.5 to -0.9 defines effective functioning of numerical tests at this level.



For the 100 numerical ability tests generated in this range, the median reliability (internal consistency) was 0.84 and the inter quartile range was 0.83 to 0.85, again indicating a high level of consistency within and across all tests generated.

Reliability of the Verbal and Numerical Tests by level

To summarise and as shown in the table below, 400 Verify Ability Tests typical of those administered to candidates at different job levels were generated. The reliability of each individual test was estimated, and the average (median) and range (inter quartile range) across all tests was used to gauge whether the reliabilities of Verify Ability Test scores are consistent across different test versions. The results show the average reliabilities of the Verify Ability Tests are equivalent to those reported for much longer traditional ability tests used in employment settings, and that the reliability of scores across different Verify Ability Tests is highly consistent.

Verify Ability Test Reliabilities	Managerial & Graduate Level Average	Supervisor & Operational Level Average	Overall Average (200 tests)
Verbal	0.81	0.78	0.80
Numerical	0.83	0.84	0.84

Reliability of the Verbal and Numerical Verification Test scores and their relationships to Verify Ability Test scores

The Verification Tests were developed to cover equivalent ranges of ability to the Verify Ability Tests. The reliabilities of Verification Test scores and their correlations (similar to a test-retest or stability coefficient) with Verify Ability Test scores are reported in the table below. Correcting for the reliabilities of corresponding SHL Verify tests provides estimates of the operational correlations between the underlying constructs measured by each type of test. As shown, these are substantial at 0.98 for verbal and 0.86 for numerical.

Verify Verification Tests	Internal Consistency	Observed correlation with corresponding Verification Ability Test Scores	Operational correlation between corresponding Verification Ability Test Constructs
Verbal	0.77	0.72	0.98
Numerical	0.79	0.70	0.86

Criterion validity of the Verbal and Numerical Test scores

While there are various facets to validity (see Burke, 2006, for a discussion of these), the most critical facet of validity for employment tests is criterion validity or the evidence showing that a test score provides meaningful predictions of work performance. This section summarises the evidence supporting the criterion validity of the Verify Ability Tests.

The purpose of validation studies is to determine the relationship between a predictor, such as the Verify Ability Test scores, and a criterion, some measure of behaviour or performance at work. The validation programme supporting the Verify Ability Tests has sought to sample jobs across a range of industry sectors and job levels, and to evaluate both the level of prediction they offer and their generalisability across different job levels and work settings. The programme has also focused on relevant criterion measures covering the types of tasks and competencies that the SHL Verify Range has been designed to predict.

Validation analyses tend to take the form of correlating criterion scores with predictor scores as per the example shown on next page. The index used to report criterion validities is generally referred to as the validity coefficient which ranges in values from -1.0 (higher predictor scores are related to lower criterion scores, or vice versa), through zero (no systematic relationship between predictor and criterion) to +1.0 (higher predictor scores are related to higher criterion scores).

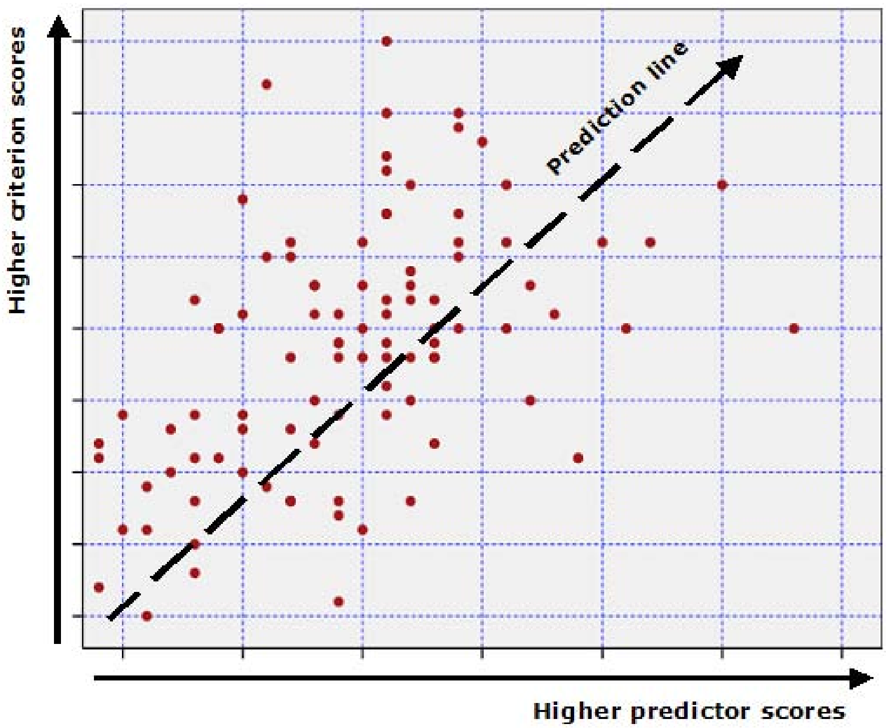
Predictors may be expected to have negative validity coefficients. An example would be when higher scores on personality scales are related to lower ratings on absenteeism, or where higher scores on, say, competitiveness are related to less effective teamwork behaviours. However, the relationships between the Verify Ability Test scores and the criterion measures reported below are expected to be positive. A positive relationship typifying those expected for Verify Ability Test scores is shown in the figure overleaf.

Using effect size benchmarks (Cohen, 1988), the strength of the relationship as reported by validity coefficients can be interpreted as follows (see also Schmidt and Hunter, 1998, for how validity coefficients can be interpreted as a percentage gain in performance):

- 0.1 = a small effect size = low validity = test scores are associated with a 10% difference in performance
- 0.3 = a medium effect size = positive benefits obtained from using the test = test scores are associated with a 30% difference in performance
- 0.5 = a large effect size = substantial benefits from using the test = test scores are associated with a 50% difference in performance

In estimating the validity of predictors such as ability tests, the size of the estimate obtained may be biased due to study artefacts. Two of the most common artefacts that impact the size of the validity coefficient are:

- **The presence of range restriction in the data**. If a validation sample has been previously selected on the predictor or some related measure, then the full range of predictor scores will not be present (usually, data from the lower score range is absent). Given that the range of predictor scores has been reduced or truncated, then the estimate of the relationship with performance criteria will tend to be biased downwards. That is, the strength of that relationship will tend to be underestimated.
- **Measurement error in the criterion**. While effort tends to be made to ensure that predictor scores are reliable and accurate (as with the Verify Ability Tests), often the same cannot be assumed of the criterion being predicted. To the extent that the criterion or criteria are unreliable, then this will also tend to bias the estimate of validity downwards.



These artefacts can be taken into account in evaluating the validity of scores when several validations have been conducted and by using the meta-analysis methods developed by Hunter and Schmidt (2004) that are widely used in personnel selection research. Several studies have been conducted as part of the SHL Verify development programme, and the next table summarises the sources of validity data used in the meta-analyses reported below. With knowledge of the sample sizes in each study, the degree of range restriction present as well as the quality of the criteria available (some criteria were existing exams and performance appraisal systems used by the clients participating), then it is possible to take into account the likely impact of artefacts on estimates of the validity of Verify Ability Test scores using the procedures as described by Hunter and Schmidt (2004).

Industry Sector	Job Level	Country	Criterion	Study Sample Size Verbal	Study Sample Size Numerical
Banking	Graduate	UK	Manager's ratings of competency	Score Not Used in Study	102
Banking	Manager	Australia	Manager's ratings of competency	221	220
Professional Services	Graduate	UK	Accountancy exam result	Score Not Used in Study	11
Financial	Supervisor	UK	Manager's ratings of competency	45	45
Financial	Operational	UK	Supervisor's ratings of competency	12	121
Retail	Operational	US	Manager's ratings of competency	89	89
Education	Operational	Eire	Performance on business education exams	72	72
			Total Sample	548	760

Note: Score Not Used in Study represents a study in which the Verify Verbal Ability Tests were not included.

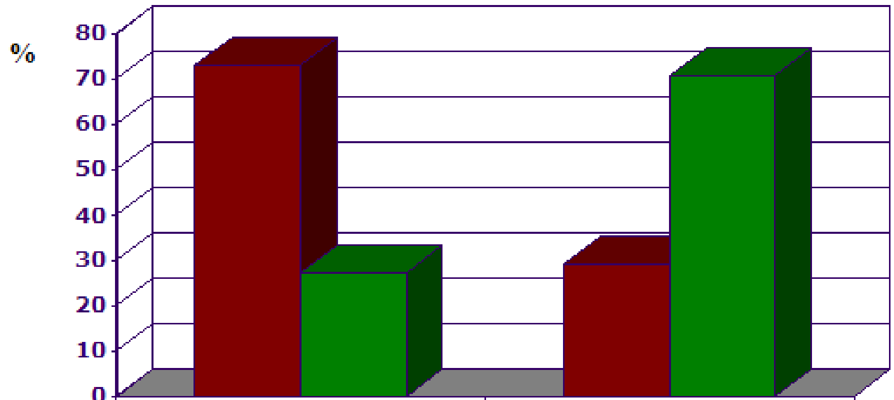
The results of the meta-analysis are shown in the table below where the key findings show that:

- The estimated operational validity for **Verify Verbal Ability Test scores** when artefacts are taken into account is **0.50**.
- The estimated operational validity for **Verify Numerical Ability Test scores** when artefacts are taken into account is **0.39**.
- **Variation in observed validities** across studies is shown to be a **factor of sampling error,** or the simple fact that estimates vary due to the differences in sample sizes across studies.
- As variation in validities is accounted for by error variance, then **the results support the generalisability of Verify Ability Test score validities** across industry sectors, job levels, types of criteria related to reasoning abilities as well as the countries included in the analysis.
- The results are **in line with** those reported in **the general scientific literature**.

Meta-analysis of Verify Ability Test score validities	Verbal	Numerical
Number of Studies (K)	5	7
Total Sample Size	548	760
Average Sample Size	110	109
Range of Observed Validities	0.21 to 0.43	0.11 to 0.34
Variance in Observed Validities (A)	0.01	0.00
Sampling Error Across Studies (B)	0.01	0.01
True Variance in Validities (A-B)	0.00	-0.01
Weighted Mean Operational Validity	0.50	0.39

The following two figures provide a graphical summary of the tangible benefits offered by the Verify Ability Test scores. This is data obtained in the USA from the retail sector and for the Junior Customer Contact level (staff in customer services and telesales). The criterion was the sum of manager/supervisor ratings across the UCF competencies of communicating, reporting, applying expertise, analysing problems and learning (competencies that the Verify Ability Tests have been designed to predict), plus an additional competency from the UCF as requested by the client, which was planning and organising. The sample size was 89 and the validities observed for this sample were 0.31 for both tests. The internal consistency for ratings across all competencies was 0.81.

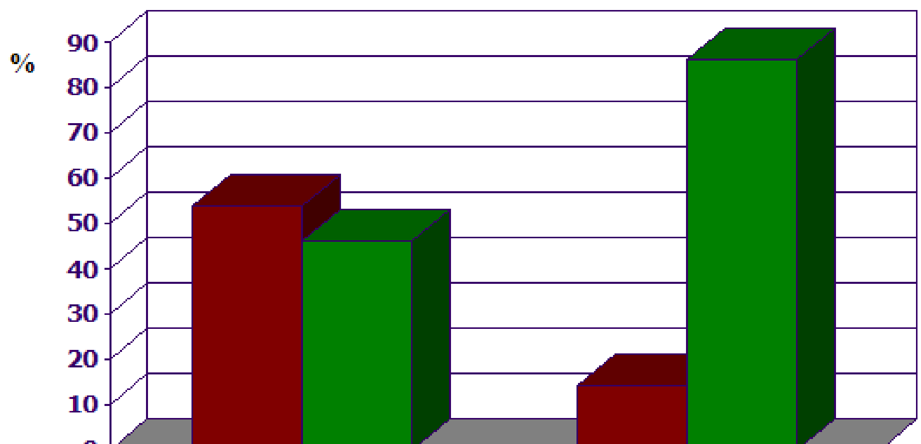
The figures show comparisons of employees falling into the highest 30% of combined scores on verbal and numerical tests with those falling into the bottom 30% of combined scores. High competency was defined as the upper quartile of manager/supervisor ratings while low competency was defined as the bottom quartile. The results show that the higher ability group had 44% more employees in the upper quartile of competency ratings.



	Lowest 30% on Verify Ability Tests	Highest 30% on Verify Ability Tests
Low competency	73%	29%
High competency	27%	71%

Ratings of employee competency broken down by higher and lower Verify Ability Test scores

The managers and supervisors were also asked to rate employees in terms of "How do you see this person's potential for advancement to a more senior role?" High potential for advancement was defined as being in the upper quartile of ratings in response to this question, while low potential was defined as the lower quartile of ratings of potential for advancement. The comparisons show that those in the highest 30% of Verify Ability Test scores had 40% more employees rated as having high potential for advancement.



	Lowest 30% on Verify Ability Tests	Highest 30% on Verify Ability Tests
Low potential	54%	14%
High potential	46%	86%

Ratings of employee potential for advancement broken down by higher and lower Verify Ability Test scores

Sample and analyses used for defining the Verbal and Numerical comparison groups

While different samples did sit different combinations of items during the trials, all score data can be included in the process of constructing comparison groups by virtue of theta scores and their properties (see the earlier section on IRT), and by virtue of the linked item design used which enables all items to be calibrated to a common theta scale. As such, the sample used for the construction of verify comparison groups for the verbal and numerical ability tests was 8,436.

The demographic breakdown of this sample shows that:

- 52% were male, 46% were female and 2% did not report their gender
- 45% White
- 23% Asian
- 8% Eurasian
- 6% Black & African
- 8% reported belonging to other ethnic groups and 10% did not report their ethnicity.

The age range of the sample was from 16 years to 66 years (to the nearest whole year), with a mean age of 28.18 years and a standard deviation of 8.11. The breakdown against equal opportunities classifications was 60% 39 years or younger, 37% 40 years or older and 3% did not report their age.

Educational level was classified as follows and in line with the O*NET classifications (see further on this below):

- Low level of formal education (no formal qualifications reported through to a secondary certificate of education as awarded at 16 years of age) = 9%.
- Moderate level of formal education (qualifications as awarded at 18 years of age) = 22%
- High level of formal education (qualifications equivalent to a university degree or postgraduate qualification) = 59%
- Not known = 10%

As will be apparent from their descriptions, all of the standardised scales used for score reporting require a central or average score to locate the scale, and a standard deviation to provide a standardised unit to measure distance from the average score. These averages and standard deviations may vary depending on the characteristics of different candidate populations. In constructing the SHL Verify Ability Range comparison groups, the following differences in candidate populations were taken into account:

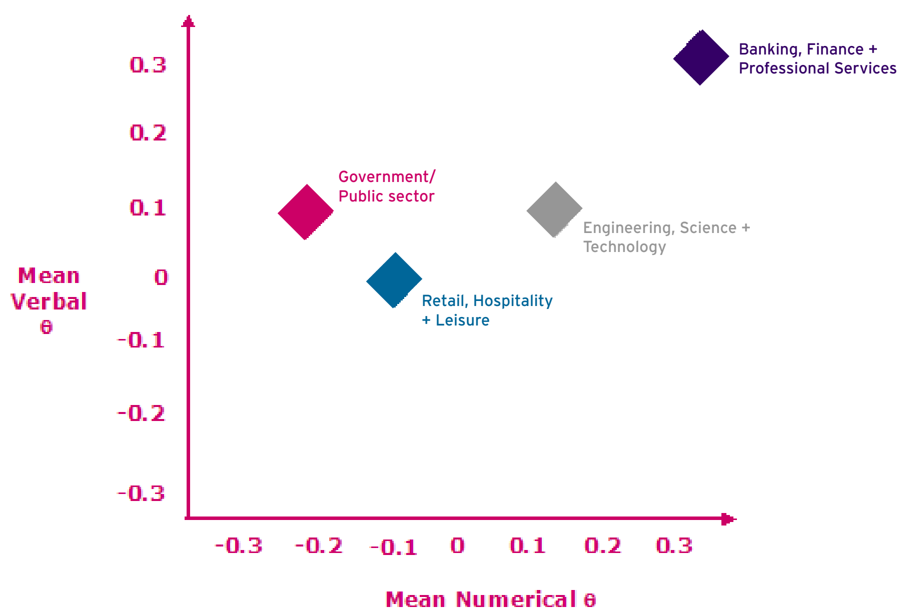
- In line with the O*NET job analysis database and research based on it (e.g. Jeanneret and Strong, 2003), one factor analysed was the relationship between educational level as reported by trial participants and performance on the Verify Ability Tests.
- Education is a significant factor related to job level in the O*NET database and the three levels described above of low, moderate and high were used to define educational bandings appropriate for different job levels as follows:

	Education Low	Education Medium	Education High
Operator	*	*	
Supervisor	*	*	
Graduate			*
Manager		*	*

A second factor analysed was the relationship between different industry sectors and scores on the Verify Ability Tests. This analysis reflects research showing that the characteristics of candidate populations can be expected to vary depending on employer brand, the career objectives of candidates as well as other factors such as candidate perceptions of the competition for employment opportunities in different labour pools.

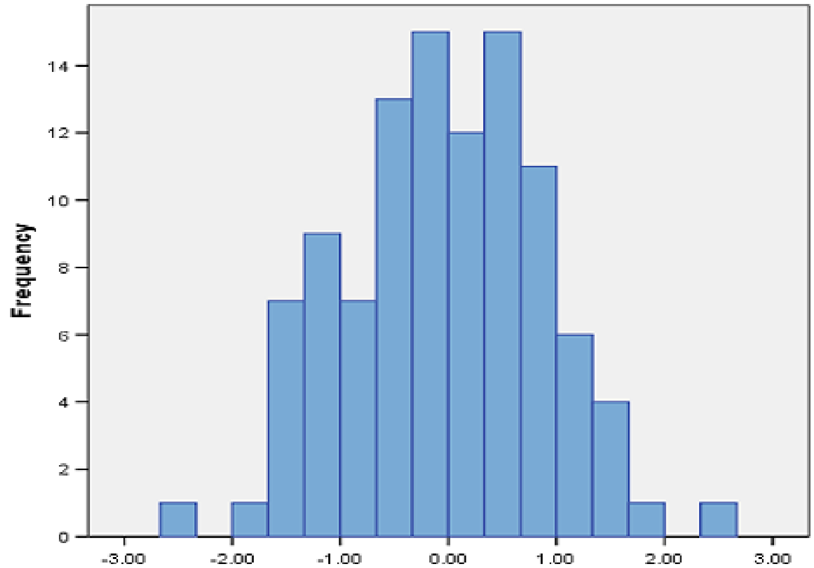
The analyses of these characteristics of candidate populations used a combination of regression and analysis of variance (ANOVA) methods. Both sets of characteristics were found to have significant associations with Verification Ability Test scores. Industry sector clusters as used in the Verify comparison groups were also obtained using the same analytic approach. These clusters and their relationship with Verify Ability Test scores are summarised in the figure below.

The 3 (educational level) x 4 (industry sector cluster) classification was used to generate the comparison groups provided with the SHL Verify Range. In addition, a general population or composite norm was created for each job level by combining all data across industry sector for that level.

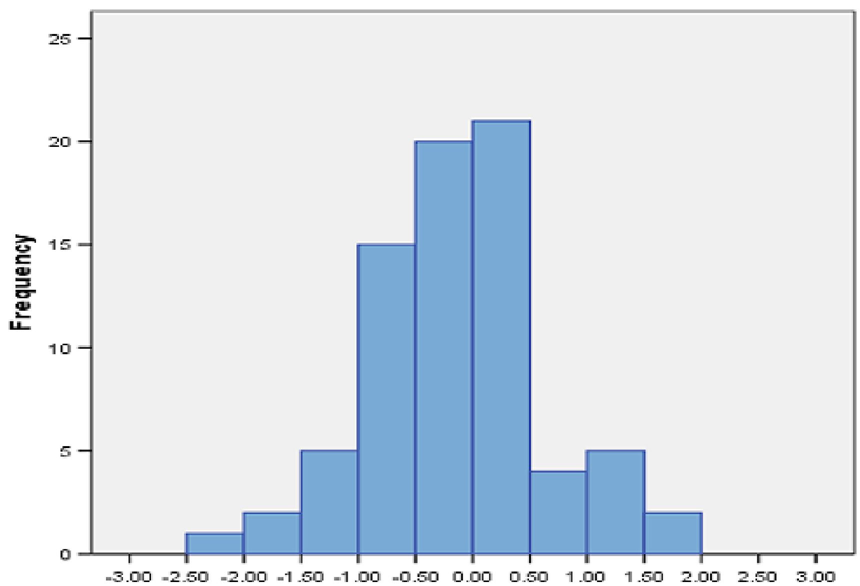


Cross-plot of average theta scores by industry cluster

The fit of these comparison group models was then evaluated using data from Verify beta sites. An example of the several evaluations undertaken is shown overleaf for Verify Verbal Ability Test score data for 103 Junior Customer Contact level staff in the retail sector. The mean standard score for this sample using the Retail Junior Customer Contact comparison group Z-score for verbal scores is 0.04 with a standard deviation of 0.91. This compares well with the expected mean of 0 and standard deviation of 1.



A second example is also given below for the fit of the appropriate Junior Manager numerical comparison group for 75 team leaders in the financial industry. The mean Z-score for this group using the finance supervisor comparison group was 0.12 with a standard deviation of 0.80.



In summary, a systematic set of analyses was used to define education levels aligned to different job levels and industry sector clusters. This 3 (educational level) x 4 (industry sector cluster) classification plus a general population composite at each job level were then used to construct the SHL Verify Range of comparison groups. The comparison groups constructed using this model were then evaluated using actual samples with known job level and industry obtained through beta sites participating in the Verify programme. Results show the comparison groups to be appropriate for interpreting Verify Ability Test scores. In total, 30 verbal and 30 numerical comparison groups are offered with the current version of the Verify Ability Tests.

Comparisons of the Verbal and Numerical Ability Test scores by sex, ethnicity and age

Differences in SHL Verify Ability Test scores were analysed by sex, ethnicity and age using data from the trials sample. Details of the demographics for the 8,436 participating in the Verify trials have been provided earlier in this manual in the discussion of the Verify comparison groups. The following provides a summary of the classifications used in the analyses reported in this section of the manual that are in line with general equal opportunities classifications:

- Sex: 53% male (reference group) and 47% female (focal group) for usable data (2% did not report their gender)
- Ethnicity: 50% White (reference group) and 50% Non-white (focal group) for usable data (10% did not report their ethnicity)
- Age: 63% 39 years or younger (reference group) and 37% 40 years or older (focal group) for usable data (3% did not report their age)

The results of these analyses are presented below. These report differences using the standardised effect size or d (see Cohen, 1988, and Hunter and Schmidt, 2004, for further details on standardised effect sizes). This computes the difference in mean scores between groups in the form of a standard deviation difference. Widely used benchmarks for d's are as follows: values of 0.3 and below are treated as small; 0.5 is treated as a medium effect size; values of 0.8 and above are treated as a large effect size.

The following table summarises the differences identified for the Verify Ability Test scores. The direction of the d reported indicates the direction of any advantage. A positive d indicates that the majority or reference group (males, White or people aged 39 or younger) had higher mean scores. A negative d indicates that the minority or focal group (females, non-Whites, people aged 40 or older) had higher mean scores.

Verify Ability Test	Differences by sex	Differences by ethnicity	Differences by age
Verbal	0.06	0.11	0.04
Numerical	0.23	0.09	0.22

In summary, small to zero effect sizes were found for the verbal scores, while the effect sizes were obtained for the numerical scores indicate a small advantage for male candidates and for candidates 39 years or younger. A near zero effect size was obtained for the comparison of numerical scores by ethnicity.

Technical details of the inductive reasoning test by general level

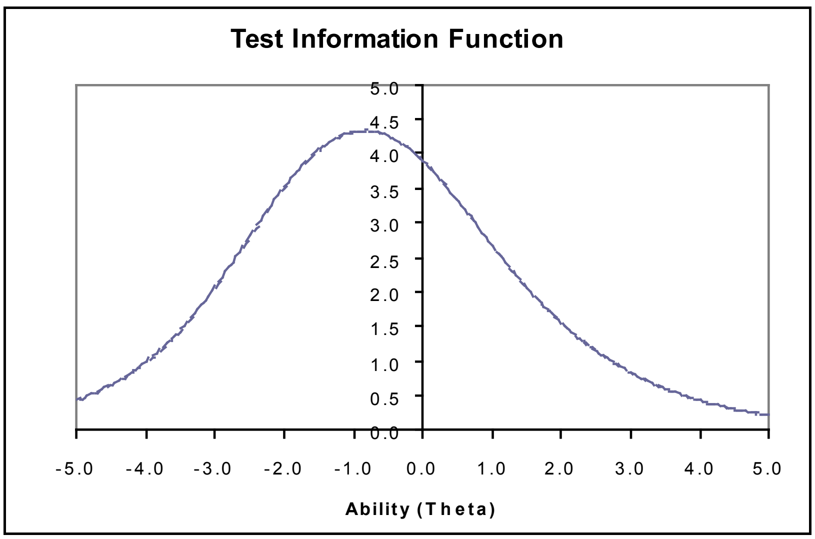
Verify Inductive Reasoning is a measure of fluid intelligence (Cattell, 1971) which is a facet of general intelligence (g). The items test the ability to draw inferences and understand the relationships between various concepts independent of acquired knowledge.

Inductive reasoning is a widely used measure in predicting job performance. Examples are Raven's Advanced Progressive Matrices (Raven, Raven & Court, 1998) and GMA Abstract (ASE, 2006). The relationship between Verify Inductive Reasoning (VIR) and other measures of inductive reasoning is described later in this manual. Inductive reasoning is occasionally referred to as a measure of abstract reasoning due to the nature of conceptual level reasoning as opposed to contextual reasoning measured in other forms of ability tests.

Inductive Reasoning Tests typifying the management and graduate levels

The figure below shows the θ range of the tests used to evaluate consistency in the quality of SHL Verify Inductive Reasoning at this level. For a test operating with a CTT reliability of at least 0.75, the target TIF value is above 4. This defines a θ range for effective functioning of tests typifying the upper end of difficulty in the Verify Inductive Reasoning item bank as lying between θ's of −1.8 to 0.

For the 100 Inductive Reasoning tests generated in this range, the median reliability (internal consistency) was 0.77 with an inter quartile range of 0.760 to 0.781, indicating a high level of consistency within and across the tests.



Reliability of the Inductive Reasoning Verification Test scores and their relationships to Verify Ability Test scores

The Verification Tests were developed to cover equivalent ranges of ability to the Verify Ability Tests. The reliabilities of Verification Test scores and their correlations (similar to a test-retest or stability coefficient) with Verify Ability Test scores are reported in the table below. Correcting for the reliabilities of corresponding SHL Verify tests provides estimates of the operational correlations between the underlying constructs measured by each type of test. As shown in the next table, this is substantial at 0.90.

Verify Verification Tests	Internal Consistency	Observed correlation with corresponding Verification Ability Test Scores	Operational correlation between corresponding Verification Ability Test Constructs
Inductive Reasoning	0.721	0.67	0.90

Relationship between SHL Verify Inductive Reasoning (VIR) and other measures

The table overleaf displays the results of a correlation study looking at the relationships between VIR and a number of alternative inductive reasoning tests used with the managerial and graduate population.

The theoretical model underlying VIR suggests certain hypotheses concerning its relationship with other tests. In particular it was anticipated that SHL Verify Inductive Reasoning should correlate higher with Raven's Advanced Progressive Matrices and GMA Abstract than other ability measures, as tests that are generally accepted as measuring Inductive reasoning.

A correlation study was carried out on a sample of 109 University students in the UK. All students completed shortened versions of SHL Verify Managerial/Graduate Level Numerical and Verbal Reasoning Tests along with VIR. Of this sample, 60 students also completed Raven's APM and 49 completed GMA Abstract Form B.

The table below provides the results of the correlations, along with correlations that have been adjusted to account for the reliability of each test. The correlations are correlated in relation to the reliabilities of each test, which are also displayed on the diagonal of the table. The reliabilities for GMA Abstract and Raven's APM are taken from the relevant manuals (Raven et al, 1998; ASE, 2006). The reliability for VIR is taken from a simulation of 100 tests.

	VIR	GMA	Ravens	Numerical	Verbal
VIR	*0.770*	0.538	0.558	0.315	0.391
GMA	0.655	*0.875*	*	0.374	0.390
Ravens	0.690	*	*0.850*	0.395	0.454
Numerical	0.404	0.450	0.483	*0.788*	0.248
Verbal	0.496	0.464	0.548	0.311	*0.808*

* Candidates who sat Raven's APM did not sit GMA Abstract to prevent test fatigue during the session

It was found that VIR has a stronger correlation with both Raven's APM and GMA Abstract than with SHL Verify Verbal and Numerical Ability (shortened) tests from the Managerial and Graduate portfolio. As a benchmark for interpreting these correlations, a correlation between GMA Abstract and Raven's was reported at 0.489 in the GMA Manual and User's Guide. The correlations reported in this manual are preliminary results and further studies will follow in a technical supplement.

The reliabilities reported in the table above reflect the lengths of the respective tests. For example, VIR consists of 24 items whereas Ravens APM and GMA comprise 40 and 115 items respectively. One concern over different reliabilities for different tests is the possible impact on criterion validities obtained by using one of those tests. This can be assessed by looking at the attenuation on criterion validities of differences in reliability. The degree of attentuation can be calculated using the formula r_{xy} X (√ r_{xx}). If an operational validity of 0.3 is assumed, then the attenuation expected using the reliability for VIR would be expected to produce an observed validity of 0.26. Using the reliabilities reported above for Ravens APM and GMA Abstract, attenuation due to reliability would be expected to produce an observed validity of 0.28. As such, the differences in reliability observed between VIR as compared to Ravens APM and GMA Abstract would be in the region of 0.02 for an operational validity of 0.3.

Measure	Length	Reliability	Administration	Configure
VIR	24	0.770	25	Online Randomised
Ravens APM	36	0.850	42 (timed)	Paper / Online Fixed
GMA Abstract	115	0.875	30	Paper Fixed

Sample and analyses used for defining the Inductive Reasoning comparison groups

While different samples did complete different combinations of items during the trials, all score data can be included in the process of constructing comparison groups by virtue of theta scores and their properties (see the earlier section on IRT), and by virtue of the linked item design used which enables all items to be calibrated to a common theta scale. As such, the sample used for the construction of comparison groups for the VIR was 7,969. A list of available comparison groups can be found on page 7.

The demographic breakdown of this sample shows that:

- 52.7% were male, 47.3% were female.
- 41.3% White
- 6.8% Asian
- 39.3% Chinese
- 7.7% Black & African
- 4.9% Other

The age range of the sample was from 16 years to 67 years (to the nearest whole year), with a mean age of 26.7 years and a standard deviation of 9.79.

Educational level was classified as follows:

- Low level of formal education (no formal qualifications reported through to a secondary certificate of education as awarded at 16 years of age) = 9.1%
- Moderate level of formal education (qualifications as awarded at 18 years of age) = 15.9 %
- High level of formal education (qualifications equivalent to a university degree or postgraduate qualification) = 70.5%
- Not known = 4.5%

Comparisons of the Inductive Reasoning Test scores by sex, ethnicity and age

Differences in Verify Ability Test scores for the Inductive Reasoning test were analysed by sex, ethnicity and age using data from the trials sample. Details of the demographics for the 7,696 participating in the SHL Verify trials are provided above. The following provides a summary of the classifications used in the analyses reported in this section of the manual that are in line with general equal opportunities classifications:

- Sex: 52.7% male (reference group) and 47.3% female (focal group) for usable data.
- Ethnicity: 41.3% White (reference group) and 58.7% Non-white (focal group) for usable data.
- Age: 90.7% 39 years or younger (reference group) and 7.7% 40 years or older (focal group) for usable data (1.6% did not report their age).

The results of these analyses are presented below. These report differences using the standardised effect size or d (see Cohen, 1988, & Hunter and Schmidt, 2004, for further details on standardised effect sizes). This computes the difference in mean scores between groups in the form of a standard deviation difference. Widely used benchmarks for d's are as follows: values of 0.3 and below are treated as small; 0.5 is treated as a medium effect size; values of 0.8 and above are treated as a large effect size.

The following table summarises the differences identified for the Verify Ability Test scores. The direction of the d reported indicates the direction of any advantage. A positive d indicates that the majority or reference group (males, Whites or people aged 39 or younger) had higher mean scores. A negative d indicates that the minority or focal group (females, non-Whites, people aged forty or older) had higher mean scores.
In summary, small to zero effect sizes were found for the VIR scores across the groups.

Verify Ability Test	Differences by sex	Differences by ethnicity	Differences by age
Inductive	0.007	-0.08	0.14

Where can I find out more information on SHL Verify?

There are a number of documents that have been developed to assist you in understanding the issues of using ability tests online and that describe the scientific research that supports the SHL Verify Range of Ability Tests and psychometric verification. These include:

- **Better Practice for Unsupervised Online Assessment –** a white paper that sets out the key issues such as laying the foundations for effective online assessment, ensuring that the science is sound, managing legal issues, and a summary of the new science of data forensics that SHL is using to audit its item banks and verify their security. This can be obtained from http://www.shl.com/SHL/en-int/Thought_Leadership/White_Papers/White-Papers.aspx
- **Better Practice Guidelines for Unsupervised Online Assessments** – which covers in more detail actions that you can take to make sure that unsupervised testing is right for your organisation, and how to develop a policy and procedures for unsupervised testing online. This can be obtained from http://www.shl.com/betterpractice
- **SHL Verify Range of Ability Tests User Guide** – which provides a quick reference to the SHL Verify Range of Ability tests. This can be obtained from http://www.shl.com/SHL/en-int/Products/Access_Ability/AccessAbility_List/verify.aspx

We have also set up an email address, **betterpractice@shlgroup.com**, through which we welcome your comments, questions and suggestions on how to improve the practice of online assessment.

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