



White Paper

COGNITIVE ABILITY: HOW IMPORTANT?

by

Tashaal Green
Griffith University Doctoral Student

and

Peter Macqueen
Principal
Compass Consulting

**MANAGEMENT
CONSULTANTS**

- recruitment
- psychological assessment
- outplacement
- career development

Level 1
47-49 Sherwood Road
Toowong Qld 4066

Phone
(07) 3870 5265
Fax
(07) 3870 5263
Email
admin@compassconsulting.com.au
Web
www.compassconsulting.com.au

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COGNITIVE ABILITY: HOW IMPORTANT?

INTRODUCTION

Employee productivity is critical in determining the success of an organisation and one of the crucial tasks for organisational psychologists is to assist businesses to select the 'best' employees from a pool of applicants. A key area of interest concerns the relationship between job performance and cognitive ability, and numerous studies have been conducted in an effort to determine whether cognitive ability is a significant predictor of job performance.

Of course, an important question is: To what extent do organisations, in Australia and overseas, employ cognitive tests as part of their approach to employee selection? Di Milia, Smith and Brown (1994), in a paper investigating management selection practices in Australia, found that nearly one quarter of Australian organisations used cognitive tests either 'always' or 'more than half' of the time. However, nearly one half never used cognitive tests. On the other hand, interviews (either one-to-one or multiple interviewers) were much more prevalent. Furthermore, the researchers found that government organisations were much less likely to use cognitive and other psychological tests.

An academic article by Salgado and Anderson (2002) investigated the use of cognitive testing in Europe, with the finding that many European countries use ability or cognitive tests more often than that which is employed within the United States. The casual reader and potential cynic may have gained the impression that 'psychological testing' (and cognitive testing in particular) is a U.S.-centric phenomenon. However, it appears that organisations within countries as diverse as The Netherlands, Spain, Portugal, Britain, Sweden, Ireland and Greece are more likely to use cognitive testing than organisations within the U.S. Interestingly, Italian organisations are the least likely to employ such tests, preferring interviews. (At least, Italian companies did not resort to the use of graphology, but even so at least 80% reported never using cognitive tests according to Shackleton and Newell (1994)). Furthermore, a recent survey by the Chartered Institute of Personnel and Development (2007) in the UK indicated that general ability tests were 'used in some way' by 72% of responding organisations and personality/aptitude questionnaires 'used in some way' by 56%.

Current figures are not available for Australian organisations, but it is fair to claim that some form of psychological testing is employed, at least irregularly, by many Australian organisations at some stage during the recruitment process.

Whilst there is a dearth of solid reporting regarding test usage in Australia, there is even a greater dearth of published validation studies. Virtually all published studies have been conducted overseas although later in this paper we refer to a small study conducted in Australia in June 2008.

GENERAL MENTAL ABILITY: A POWERFUL PREDICTOR

General Mental Ability (GMA) encompasses the ability to learn and adapt, with emphasis on the importance of complex information processing through problem solving, conceptual thinking and reasoning (Ones, Viswesvaran & Dilchert, 2005).

Cognitive or mental ability is one of the most widely researched psychological constructs. The U.S. Military was the first to conduct large scale ability testing, assessing almost two million individuals during World War I. This testing initiated considerable interest, with private sector organisations adopting cognitive testing for their business needs. As testing of GMA became more widespread, researchers began to deviate from the idea of an overarching mental ability, focusing on procedures that were intended to test multiple, specific abilities (for example, mathematical, verbal and mechanical skills). As these tests could be specifically designed to include more or less of a particular ability, they were tailored to individual jobs according to the skills and abilities deemed important to the particular job. This tailored assessment became the dominant method for personnel selection, until research exploring the links between the results of ability tests and employee performance revealed varying levels of validity, despite the same assessment procedures being used for the same jobs. This phenomenon, labelled '*situational specificity*', resulted in the belief that the validity of a test could not be generalised from one situation to a similar situation due to subtle differences between the two jobs.

In the late 1970s the theory of situational specificity was rebuked when advances in quantitative research techniques (meta-analysis), primarily through the seminal work of John Hunter and Frank Schmidt, enabled researchers to determine that the differences in validity previously found were due to statistical and measurement error, rather than as a result of subtle job differences. Furthermore, meta-analytic techniques enabled researchers to more accurately decipher the relationship between GMA and job performance, leading to a resurgence of interest in the field.

The increase in studies investigating the relationship between GMA and job performance resulted in a more in depth exploration of the structure of intelligence, culminating in the establishment of the three-stratum theory of cognitive abilities, the most widely accepted theory of GMA.

Proposed by John B. Carroll (1993), the three-stratum theory of cognitive abilities (not to be confused with Jaques' stratified systems theory) organises intellectual abilities into three distinct levels. The *third level* embodies a single measure of general intelligence, representing GMA. The *second level* details eight broad ability factors. The justification for distinguishing these broad abilities from GMA is to better explain individual differences in cognitive

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ability. By separating general mental ability into eight distinct ability factors, Carroll illustrated why some individuals do well in particular ability tasks (which incorporate one or more of the specific ability factors the individual excels in) but not in others (which incorporate one or more of the specific ability factors the individual may lack) The *first level* divides the eight broad ability factors of level two into more specific abilities that are more homogenous than those of level two.

JOB PERFORMANCE: THE CRITERION ISSUE

The plethora of published studies investigating job performance (both at the individual and group level) highlights the importance of job performance to industrial and organisational psychologists. Researchers in the 1960s and 1970s were primarily focused on ratings formats; those in the 1980s and early 1990s predominately investigated issues pertaining to rater cognitive processes; and recent researchers have been concerned with 360 degree feedback systems. Despite the shifting focus of interest in this field, one enduring challenge for researchers has been the inherent difficulty in defining and assessing job performance, given its multidimensionality.

Job performance can be defined in relation to:

- *quantifiable work behaviour outcomes* (for example, an employee's sales figures), or
- *behavioural dimensions* - which are more difficult to quantify (for example, attention to detail).

In addition, job performance can be defined in relation to:

- *task performance* (those activities formally recognised as core components of the job), or
- *contextual performance* (those activities that contribute to the social environment of the organisation – or 'organisational citizenship behaviour', commonly known as OCB).

Depending on which definition of job performance is applied, information on an individual's performance can be obtained from multiple sources, including:

- *objective indexes* which are countable and directly observable (for example, sales volume), or
- *subjective indexes* which are based on judgements of others (for example, ratings by an individual's supervisor or colleagues).

Most organisations however, use subjective indices, which require raters (usually supervisors) to make subjective judgements concerning the performance of employees. These subjective judgements often take the form of ratings or rankings, and are collected using a variety of rating formats; the most widely used being graphic ratings scales.

Graphic ratings scales provide the rater a set of task categories considered important to the job, requiring the rater to evaluate an individual's performance on the task categories using a polarised scale. For example, a rater may be asked to evaluate an individual's performance using a scale ranging from 1 (where the individual does not meet expectations) to 5 (where the individual surpasses expectations).

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For the purposes of this White Paper, job performance is defined in terms of an individual's task performance. Often the job (task) performance rating is obtained from the individual's supervisor. Not only can subjective criteria be vulnerable to bias and error but also reliability estimates can vary depending on the nature and context of the measurement. Viswesvaran, Ones and Schmidt (1996), notable U.S. researchers in the field of personnel selection, state that the mean coefficient alpha is .86 for supervisory ratings of job performance, but the mean inter-rater reliability estimate is only .52. In other words, an individual rater is reasonably consistent in their ratings – but there can be disagreement between ratings of the one individual by different raters.

Furthermore, whilst job performance has been defined and assessed using a variety of methods, a recent comprehensive meta-analytic study has revealed that these different methods are positively correlated (Viswesvaran & Ones, 2007). The results of this study suggest that there is a common factor underlying the different measures and assessments of job performance, implying that employees who perform well in one dimension are likely to perform well in other dimensions. GMA is one of the factors which has been hypothesised to predict, and to have an impact on, an individual's job performance.

Finally, it should be highlighted that 'the criterion problem' in psychology rears its head quite clearly when we discuss 'job performance'. In a very recent series of papers, several authors discuss/debate the (weak?) relationship between job performance and ratings of job performance (*Industrial and Organizational Psychology: perspectives on science and practice*. June 2008, vol 1(2). Published by Society for Industrial and Organizational Psychology).

THE LINK BETWEEN GENERAL MENTAL ABILITY AND JOB PERFORMANCE: THE RESEARCH

Following Schmidt and Hunter’s (1977) meta-analytic review which dismissed the theory of situational specificity, numerous researchers have carried out similar meta-analyses. These meta-analyses, conducted in the USA and Europe, have demonstrated consistently that GMA and cognitive ability tests are valid predictors of job performance. [See, for example: Hülshager, Maier & Stumpp, 2007; Hunter & Hunter, 1984; Pearlman, Schmidt, & Hunter, 1980; Salgado, Anderson, Moscoso, Bertua & De Fruyt, 2003].

Whilst these studies found that validity estimates across personnel selection situations remain constant, variation occurs between jobs. Hunter and Hunter (1984) found *job complexity* is a significant moderator variable in the relationship between GMA and job performance. Using data obtained from 425 validity studies (n= 32,124) conducted on a diverse range of civilian jobs, the two authors reported the results illustrated in Table 1.

**Table 1:
Validity of the GMA Measure in the General Aptitude Test Battery**

Complexity Level of Job	Performance Measures (on the Job)
1 professional-managerial	.58
2 complex technical	.56
3 medium complexity	.51
4 semi-skilled	.40
5 unskilled	.23

Note: *The figure of .51 is cited often in the literature as 62% of jobs in the U.S. economy fall in this category.*

The authors categorised each job into one of five job families defined by complexity (where complexity was measured by the information processing requirements of the job). To date, this meta-analysis is the most extensive review which employs a measure of performance on the job (measured by supervisor ratings of job performance) (Schmidt & Hunter, 2004). As can be seen in Table 1, validity for predicting performance on the job ranges from .58 for professional-managerial jobs to .23 for unskilled jobs. Although the operational validity of GMA tests is higher as the job increases in complexity, Schmidt & Hunter (2004) claim that there is substantial validity for all job levels. However, it is evident that cognitive ability is unlikely to be the single best predictor of job success for lower level jobs. Other important psychological factors to consider include diligence, safety awareness and customer service orientation. Box 1 on the next page provides the general reader with assistance in understanding the numbers.

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BOX 1 WHAT THE NUMBERS MEAN

Reliability (Accuracy)

A measure of consistency, producing a correlation coefficient ranging from zero to one. Although other factors do need to be considered (for example, sample size and context), reliability coefficients may be evaluated as follows:

⇒ .85	-	excellent
⇒ .8	-	good
⇒ .7	-	reasonable
⇒ .6	-	adequate

Validity (Relevance)

A multi-faceted construct with both conceptual and statistical definitions. Tests do not have validities. It is the inferences made, based on the test scores, that have validities. For example, whilst tests of cognitive ability have been shown to be valid predictors of job performance, they are probably not valid predictors of ability to 'benchpress' in the gym!

Predictive and concurrent validities (correlation coefficients), ranging from zero to one, may be evaluated as follows:

⇒ .55 +	-	excellent
⇒ .45 to .54	-	good
⇒ .35 to .44	-	reasonable
⇒ .2 to .34	-	adequate

- NOTES:**
1. Some psychometricians argue that a correlation coefficient of .3, even if statistically significant, may be meaningless. Then again, others argue that a predictive validity of .20 may offer 'utility', depending on the situation or context.
 2. Percentage of variance (or overlap) between the predictor(s) and the criterion is equal to the square of the correlation coefficient. Thus, for a predictive validity of .6 (excellent), the predictor(s) accounts for 36% of the variance in the criterion.

Source: Adapted from Smith with Smith (2005, pp. 122 & 159).

Studies conducted by other researchers have obtained similar results. Pearlman, Schmidt and Hunter (1980) investigated the mean validity of job performance for clerical workers and found it to be .52. In a multi-year military study involving enlisted U.S. Army personnel, McHenry, Hough, Toquam, Hanson and Ashworth (1990) found GMA predicted 'general soldiering performance' with a validity of .65. Furthermore, Salgado et al (2003) conducted a meta-analysis using European studies and found the mean corrected (for range restriction and criterion unreliability) operational validity of GMA measures for predicting job performance was .62. These meta-statistics are significant and meaningful.

Researchers have also investigated the question of *general* versus *specific* cognitive abilities as predictors of job performance. Meta-analyses have examined the criterion validity of specific cognitive abilities (verbal, numerical, and problem solving) and found that specific abilities do not appear to add incremental validity to predictor-criterion relationships (Bertua, Anderson & Salgado, 2005). These meta-analyses have examined the individual incremental validity of specific cognitive tests, rather than their validity in conjunction with other specific ability tests as part of a comprehensive test battery. However, tests of specific cognitive abilities are often the central component of

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recruitment and selection procedures of many Australian organisations which employ separate tests of verbal, numerical and abstract reasoning, rather than relying on a single cognitive test.

Despite the plethora of published studies attesting to the validity of GMA and cognitive ability tests in predicting job performance, the current literature has limitations. One limitation is that many of the studies conducted examine GMA as a predictor of job performance, rather than investigating the predictive validity of particular cognitive abilities (Bertua et al., 2005). Another limitation is the reliance on U.S. samples of studies investigating the relationship between GMA and job performance. The findings of U.S. studies and meta-analyses have been cited as being generalisable to other countries (Herriot & Anderson, 1997). However, a limitation of this viewpoint is that it does not allow for the potential impact of differences in the cultural, social, recruitment and performance measures between the U.S. and other countries. While this may overlook European studies (for example, Salgado & Anderson, 2003) which have replicated the U.S. findings, there does remain the issue of the potential for significant outcome differences as noted by Bertua et al. (2005). Furthermore, the rapid growth in the economies of China and India (as well as Brazil and Russia) may encourage researchers to consider a broader and non-western canvas. However, it should not be taken for granted that there will be significant differences in the criterion and predictor domains. As noted in the '[Personality at Work](#)' White Paper by Compass Consulting, a Thai study provided further support for the Big 5 model that was developed in the U.S.

In an effort to address the lack of research conducted with Australian applicants, this White Paper presents evidence linking cognitive ability and job performance using an Australian sample. Cognitive ability will be measured using three tests which assess specific cognitive abilities, to determine the extent to which each (and all) of the cognitive abilities predicts job performance.

AUSTRALIAN STUDY: SUMMARY ONLY***Participants***

Participants were 37 professionals, supervisors and managers working in a diversified industrial organisation. Each participant completed three cognitive ability tests as part of the selection assessment procedure. Job levels ranged from graduate appointments to senior management roles. The sample was 54% male ($n=20$), with age ranging from 21 years to 52 years.

Materials

Three tests designed to measure specific mental abilities were used:

- *Verbal Critical Reasoning (VMG2)* – The test consists of 48 questions. Candidates are given 25 minutes to complete the test. The internal consistency reliability for this test is .85 (SHL, 2005).
- *Numerical Critical Reasoning (NMG2)* – The test consists of 35 questions. Candidates are given 35 minutes to complete the test. The internal consistency reliability for this test is .90 (SHL, 2005).
- *Raven's Standard Progressive Matrices (SPM)* – The SPM is generally regarded as a good measure of the non-verbal element of GMA (Rushton & Skuy, 2000). Developed as a power or untimed test, candidates are given 20 minutes to complete the test, as is the norm in Australia. However, in pursuing a diagnostic approach, Compass Consulting does occasionally allow very slow individuals extra time, with the answer sheet inspected subsequently for error rate and alternative norms employed. For this study, only the result from the base 20 mins testing was considered. The internal consistency reliability for this test is .80 (Rushton & Skuy, 2000).

Job performance was assessed using ratings obtained from a senior human resource officer/psychologist within the organisation. This one individual rated each participant using a five point Likert scale, where a value of 1 = poor performance and 5 = exceptional performance.

Procedure

Prior to the commencement of the study, each participant completed the three abovementioned tests as part of the company's selection process. Participants completed paper and pencil versions of each test under the supervision of a qualified psychologist. Each participant subsequently accepted an offer of employment from the company. Each participant's raw score ability test results and performance ratings were entered into an SPSS database and analysed using various statistical procedures.

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Results

The first series of analyses conducted examined the predictive validity of GMA and specific cognitive ability test results as predictors of job performance. Simultaneous regression was conducted to determine if and how results of each of the specific ability tests combined to influence job performance.

Analysis 1

Simultaneous regression was conducted as the aim of the study was to examine the relationship between the whole set of predictors and the dependent variable (performance).

The observed validity R is .37 and the overall R² value in this analysis (using all three independent variables) is .14, indicating that all three variables together account for 14% variance of job performance. An analysis of variance (ANOVA) produced a non-significant result (F = 1.78, probability > .17). That is, based on the observed data, there was no significant relationship between any (or all) of the predictors (tests) and the ratings of job performance.

Analysis 2

It was also considered pertinent to review the extent to which the individual tests correlate with each other. That is, the extent to which each test is considered to share substantial common variance and thus providing support for the notion of a construct entitled 'Reasoning Ability' (in effect, General Mental Ability). Correlations are presented in Table 2.

**Table 2:
Test Inter-Correlations for Performance Group (n=37)**

	VMG2	NMG2	SPM
VMG2	1	.66**	.37*
NMG2	.66**	1	.32
SPM	.37*	.32	1

** Each of these correlations is highly significant (p < .01).

* Each of these correlations is significant (p < .05).

Accordingly, the tests reveal substantial overlap with each other.

The results for a full data set (representing all individuals tested, n = 188 to 252, depending on test) reveal all inter-correlations to be significant at the p < .01 level. The weakest inter-correlation exists between the VMG2 and the SPM. This is consistent with the fact that the VMG2 is a verbal (comprehension) test whereas the SPM is a non-verbal reasoning test. At the same time, there is an underlying general intelligence factor.

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Discussion (including 'technical stuff')

The overall finding from this research project is that GMA and specific cognitive ability tests do not appear to be valid predictors of job performance when observed validities are considered. However, it is necessary to invoke corrections similar to those which have been incorporated in the overseas research studies. Statistical (un)reliability places a 'cap' on the maximum validity that can be achieved. Range restriction also leads to an underestimate of the validity or predictive relationship as discussed below. Corrections for range restriction and unreliability are important to conduct in order to estimate operational validities.

Predictor (Test) Reliability

Reliabilities for the three tests (internal consistency and test-retest reliability) range from .83 to .93 for the three predictors. In a review of primary studies using GMA, a German study (Hülshager, et al., 2007) suggests reliabilities from .91 to .92. However, the study in this White Paper used the figure of .81 as did Hunter and Hunter (1984). This figure is also very close to that of .83 as used by Salgado and Anderson (2003).

No direct adjustment has been made for direct predictor reliability, although this is included in the range restriction correction as noted below.

Range Restriction

As Sackett and Yang (2000) note, range restriction is a significant issue for research in personnel selection, as organisations are often reluctant to employ individuals who perform poorly on a certain assessment activity. Those with low ability scores are less likely to be offered employment and therefore less likely to contribute to a predictive study. Sackett, Borneman and Connelly (2008) note that range restriction leads to under-estimates of validity.

Salgado et al. (2003) found a range restriction ratio (μ_x) of .62 (SD sample/SD population) for job performance. This is almost identical to the range restriction ratio of .63 obtained by Salgado and Anderson (2003).

However, Hunter, Schmidt and Le (2006) note the importance of direct as well as indirect range restriction and recommend employing a modified range restriction ratio (μ_T) incorporating the reliability of the sample predictor(s). Accordingly, this study will make use of $\mu_T = .49$, based on $\mu_x = .62$ and the average reliability measure of .81.

The adjusted validity, accounting for range restriction alone, is as follows:

$$R_{adj} = .61$$

This represents a substantial increment to the observed R value of .37.

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Criterion Reliability

The reliability of the criterion measure is problematic. The maximum value of a validity coefficient is a function of the reliability of the predictor(s) and the reliability of the criterion. In effect, the reliability acts as a ceiling on the maximum validity that can be obtained.

On this occasion, one person provided performance ratings for all 37 participants. It cannot be assumed that only systematic error occurred in the ratings as knowledge of actual job performance would have varied across participants. The ratings were based on direct observation and knowledge, as well as reputation and filtered feedback from other sources. Viswesvaran et al (1996) indicate the reliability of a performance rating by a single supervisor is only .52. This value is also used by a more recent European study (Salgado & Anderson, 2003) and the very recent paper by Sackett et al. (2008).

Employing this second correction factor (.52) for criterion unreliability produces the final operational validity results:

$$R_{op} = .84$$

This indicates that about 70% of the variance in job performance can be accommodated by the three cognitive ability test results alone. This result is stronger than that published by Bertua et al (2005) who found operational validities of .74 for professionals and .70 engineering personnel. (The sample in this study has a strong professional and engineering bias).

Whilst not all psychometricians may agree on the merits of this second adjustment, the more conservative estimate (.61) is still impressive and consistent with the data presented in Table 1. The issue of range restriction for the criterion is unlikely to be a significant issue in that the individuals in this study included those who had left the organisation (and who were perhaps more likely to be rated poorly) as well as current employees. Furthermore, it can be argued that both good performers and poor performers would come to the attention of the rater.

Sample Representativeness

A further analysis noted a significant difference in test scores between the performance group versus the balance of others tested within the organisation. The test group was drawn from one business unit of the organisation and professionals may be over-represented in this group. This may account for the difference in mean test scores.

LIMITATIONS

The results of this brief study should be interpreted with regard to its limitations:

▪ *Sample size*

A larger sample size would have increased the effect size of the data and potentially resulted in different results.

- Kline (2005) recommends ten cases per variable for a simultaneous regression analysis whereas Coakes and Steed (2001) prefer 20 cases per variable. Accordingly, a sample size in excess of 120 (and including a representative sample from the organisation as a whole) would have enabled the use of a cross-validation technique. This would have allowed for the testing of the original regression equation model against data in the 'holdout' group.
- A larger sample size may have allowed the researchers to make use of the 'job level' ratings. As noted by Schmidt and Hunter (1998), in an important review paper, predictive validity varies across job complexity levels.

▪ *Performance Ratings*

The use of subjective ratings of individual performance as a basis for personnel decisions has several limitations. Performance ratings are susceptible to systematic errors (including the halo effect, leniency, recency and contrast); can be manipulated by the rater for their own goals (including social and political motives); and depend on the rater's cognisance with, and opportunity to, accurately observe job behaviour (Newman, Kinney and Farr, 2004). According to Ones, Viswesvaran and Schmidt (2008), one would need nine performance raters to achieve a reliability level in the .90 range. While this is highly unlikely to occur in practice, more than one rater would enhance the reliability.

Furthermore, only one criteria was used to assess job performance. We have not obtained a rating with respect to contextual performance, team performance, OCB and the like.

▪ *Extraneous Conditions*

The Australian labour market during the time the research was conducted may have impacted on the results in that there was a shortage of suitable candidates seeking employment. This in turn may have affected the mean test scores and the mean performance ratings, but not necessarily the validity coefficients.

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CONCLUSION

The results of this study reveal that, after correcting for statistical artefacts, cognitive ability tests are valid predictors of job performance in the Australian context. This finding is consistent with research conducted internationally. Whilst limitations in this study have been noted above, it is pleasing to find hard data to support the ongoing practice of cognitive ability testing as a means of enhancing selection decisions when employing personnel. Box 2 below provides a very useful summary of the importance of cognitive ability at work.

BOX 2 THE IMPORTANCE OF COGNITIVE ABILITY AT WORK

1. Higher levels of cognitive ability lead to higher levels of performance on all jobs.
2. There is no ability threshold.
3. Cognitive ability predicts job performance better in more complex jobs.
4. Cognitive ability predicts the core technical dimension of performance better than it does the non-core 'citizenship' dimensions of performance.
5. Cognitive ability predicts objectively measured performance better than it does subjectively measured performance (such as supervisor ratings).
6. Specific mental abilities (such as mechanical reasoning) add very little beyond GMA, although can be quite useful in specific jobs.
7. GMA predicts core performance much better than do 'non-cognitive' predictors such as vocational interests and different personality traits.
8. However, GMA predicts most dimensions of non-core performance (such as personal discipline) much less well than they do 'non-cognitive' traits of personality and temperament.
9. Experience predicts job performance less well as job complexity rises. Like general psychomotor ability, experience matters least where GMA matters most to individuals and their organisations.

Source: Adapted from Gottfredson (2002, pp. 44-46) and Furnham (2008, pp. 200-201).

Furthermore, Adrian Furnham's very recent book, 'Personality and intelligence at work: Exploring and explaining individual differences at work', is a recommended book for all readers.

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ABOUT THE AUTHORS

Peter Macqueen, Principal of Compass Consulting, has over 20 years experience in Management Consulting. He is a Registered Psychologist and a Member of the College of Organisational Psychologists (Australian Psychological Society). He is also a Member or Foreign Affiliate of several overseas organisations: British Psychological Society; American Psychological Association; International Association of Applied Psychologists; International Test Commission and Society of Industrial and Organizational Psychology. He is a Fellow of the Institute of Management Consultants and an Associate Fellow of the Australian Human Resources Institute.

Peter has lectured in Psychological Assessment to postgraduate students at Griffith University. He has served as Secretary on the Qld Committee of the Board (now College) of Organisational Psychologists. Peter was also a member of a six person standing sub-committee of the National Committee charged with reviewing Psychological Testing and Assessment in Australia.

Tashaal Green has recently completed an honours degree in psychology and is currently completing a doctorate degree (organisational psychology) at the School of Psychology, Griffith University. She is provisionally registered with the Queensland Registration Board of Psychologists.