Cognadev Technical Report Series

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24th July, 2014

The Cognitive Process Profile (CPP) and Cognitive Ability

Analyzing and reporting upon the relationships between CPP attributes and scale scores from three ability and reasoning assessments:

MAB-II *Sigma Assessment Systems*
Multidimensional Aptitude Battery (MAB)

PSYTECH INTERNATIONAL
GRT2 General Reasoning Test
CRTB2 Critical Reasoning Test

cognadev

Paul Barrett, PhD.
Chief Research Scientist

18B Balmoral Ave
Hurlingham Sandton 2196
Johannesburg
South Africa

Tel: +27 11 884-0878
Fax: +27 11 884-0910

19 Carlton Road
Pukekohe
Auckland 2120
New Zealand

Tel: +64 9 889-2630
Mob: +64 21-415625
Fax: +64 9 280-6121
Skype: pbar088

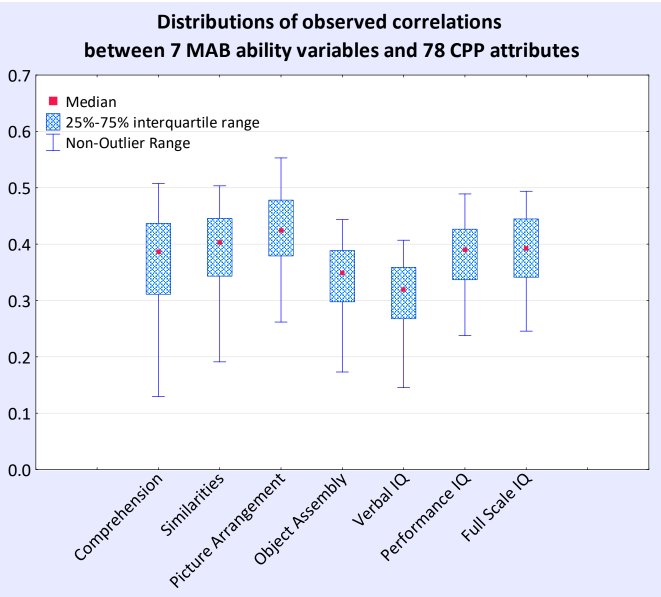
www.cognadev.com paul@cognadev.com

Cognadev UK Ltd., 2 Jardine House, Harrovian Business Village, Harrow, Middlesex, HA1 3EX. Registered UK # 05562662

Executive Summary

Study 1: The CPP & Multidimensional Aptitude Battery (MAB: Sigma Assessment Systems)

Sample: 161 respondents, comprising a mixture of university students, employees, and adult volunteers, all tested within South Africa. Of these respondents, 149 completed the CPP.



Plotting the varying correlations for 78 CPP attributes for each of 4 MAB ability subscales and Full-Scale IQ scores as a median/inter-quartile range box-plot, so as to view the overall density of correlation magnitudes.

Variable	CPP Levels of Work x MAB ability scales Kruskal gamma correlations	
	Level of Work	Potential Level of Work
Comprehension	0.47	0.40
Similarities	0.45	0.42
Picture Arrangement	0.49	0.41
Object Assembly	0.46	0.33
Verbal IQ	0.34	0.34
Performance IQ	0.41	0.34
Full Scale IQ	0.41	0.37

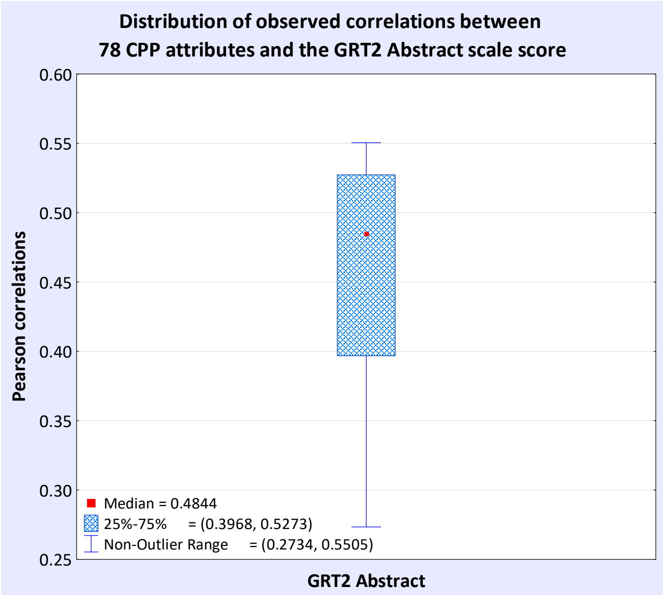
Kruskal Gamma correlations were computed between the two CPP Level of Work attributes and MAB ability scales.

Study 2: The CPP & General Reasoning Test Battery (GRT2: Psytech International)

Sample: 259 South African employment candidates assessed within a recruitment process by an organizational development consultancy. 143 cases completed the CPP, with 138 cases with complete data on both the CPP and GRT2 Abstract Reasoning scale.

Variable	Gamma Correlations between GRT2 and CPP Level of Work attributes n = 138
	GRT2 Abstract
Level of Work	0.49
Potential Level of Work	0.51

Gamma correlations between CPP current and potential Level of Work and GRT2 Abstract scores.



Plotting the varying correlations for 78 CPP attributes with the Abstract scale scores as a median/inter-quartile-range box-plot:

Study 3: The CPP & Critical Reasoning Test Battery (CRTB2: Psytech International)

Sample: 128 South African employment candidates assessed within a recruitment process by an HR consultancy; score data supplied for the Numerical and Verbal subscales of the CRTB2.

	HR consultancy candidates (SA) n=128	
Variable	CRTB2-Numerical	CRBT2-Verbal
Pragmatic	0.42	0.26
Exploration	0.56	0.44
Analytical	0.57	0.41
Rule Orientation	0.60	0.44
Categorisation	0.47	0.33
Integration	0.64	0.50
Complexity	0.63	0.48
Logical Reasoning	0.58	0.41
Verbal Abstraction	0.54	0.41
Use of Memory	0.48	0.43
Memory Strategies	0.59	0.52
Judgement	0.64	0.49
Learning 1	0.62	0.50
Learning 2	0.37	0.27

Pearson correlations for the 14 CPP competencies and the two CRTB2 scale scores.

	Gamma correlations - HR consultancy candidates (SA) n=128	
Variable	CRTB2-Numerical	CRBT2-Verbal
Level of Work	0.62	0.48
Potential Level of Work	0.60	0.37

Overall Conclusion

While the CPP attributes are clearly related to MAB abilities/IQ, and GRT2, CRTB2 reasoning scales, the various analyses show that there is substantive information assessed by the CPP which is not assessed by the ability assessments. From a theoretical perspective, this is just about right as the CPP would be expected to engage an individual’s cognitive abilities, but not to the extent that performance on the CPP would be a direct function of those abilities.

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Study 1: The Cognitive Process Profile (CPP) & The Multidimensional Aptitude Battery (MAB)

Aim: to explore the relationships between attributes assessed by the CPP and ability subscales/full-scale IQ as assessed by the MAB.

Sample: 161 respondents, comprising a mixture of university students, employees, and adult volunteers, all tested within South Africa. Of these respondents, 149 completed the CPP.

Table 1: Sample descriptive statistics for CPP v MAB dataset (n=161 in total)

	Respondent Age descriptive statistics, by Gender (total n=161)							
Gender	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
Females	136	21.44	19	17	50	18	22	6.039
Males	25	21.88	20	18	38	19	23	5.262

Assessments

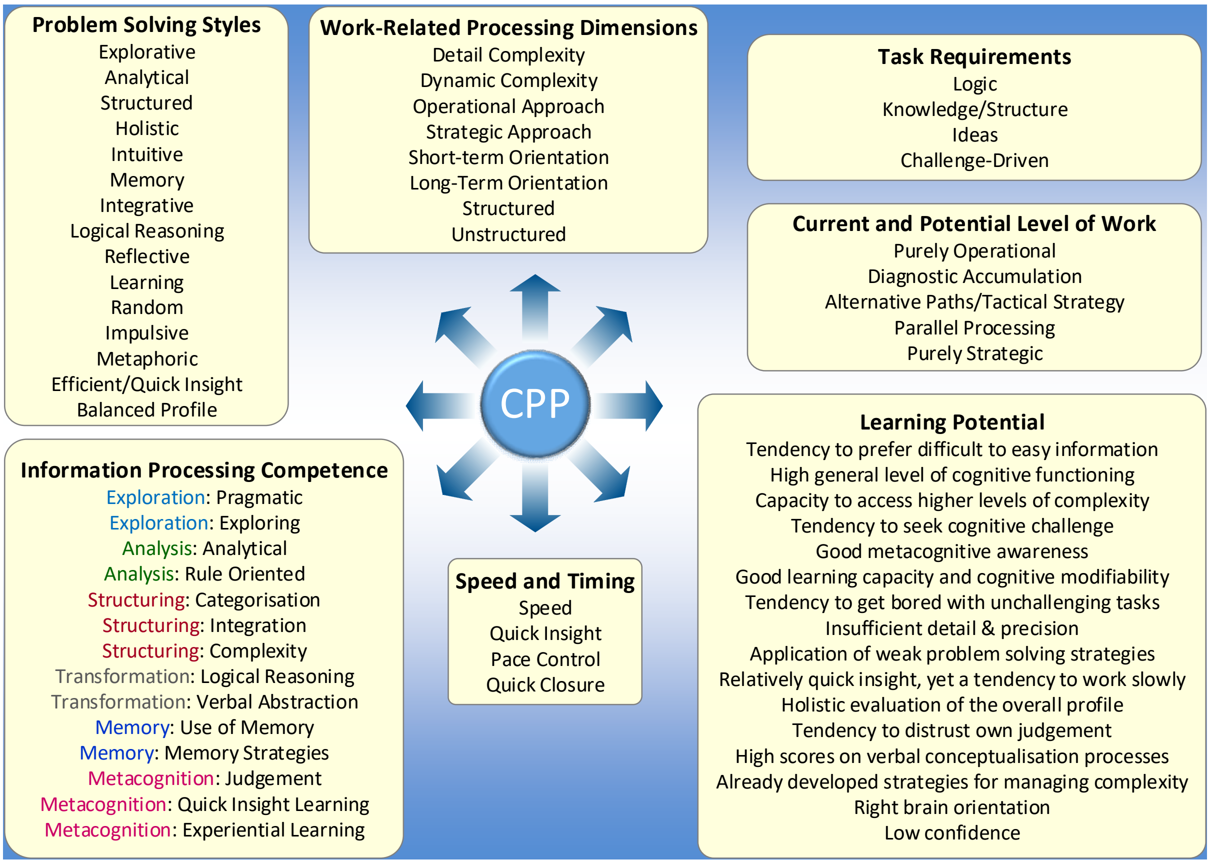
The CPP

- The CPP is based on a self-contained model of thinking processes – where all "processing constructs" have been broken down into their subcomponents at increasingly detailed levels
- These "micro processes" are then operationalised and a task developed which allows for the detailed measurement of these basic information processing skills.
- The CPP "game", which can partly be described as an assessment centre / simulation exercise, has thus been devised to "externalise" the thinking process so that the computer can track it (according to thousands of measurement points and feedback loops), via the movement of cards on the computer screen and a candidate's conceptualisations.
- This reflects the view of "intelligence" in terms of the process by which people meaningfully interpret/ understand their world.
- The CPP involves 8 stories written in symbols, which have to be deciphered using clue cards/ information cards.
- There are different types of information cards that the person can use depending on personal preferences and "what comes natural". The types of information cards include: symbols, rules, fuzzies at various levels of fuzziness, predictors, catalysts / change cards, hypotheses cards and sequences, visuals, optional information, irrelevant cards, etc.
- The way in which the person opens and moves these cards, and finally interprets meaning, provide information on his/her processing preferences.

The CPP is an advanced computerised assessment technique, designed to measure thinking processes and styles and to link these to everyday cognitive functioning. The idea behind the CPP is to move assessment of performance attributes beyond the concept of general intelligence and GMA. Using simulation exercises, subjects are monitored on their ability to explore, link, structure, transform, remember, learn and clarify information. The results are linked to job-related performance.

In terms of the cognitive attributes/processes assessed by the task, Figure 1 below provides a detailed overview.

Figure 1: The Attributes assessed by the CPP



- **Cognitive styles/Problem Solving Styles** (i.e. a person's general approach to problem solving - particularly in new and unfamiliar situations)
- **Information Processing/Cognitive processes/Competencies** (i.e. the performance processes used to manage task material)
- **Work-related processing aspects** (e.g. indicating the levels of work reflecting the Stratified Systems Theory of Jaques or the Viable Systems Model of Beer)
- **Timing / pace control** (where "speed" is a separate construct to "power")
- **Task Requirements** and associated processing tendencies
- **Current and Potential Level of Work**. Algorithms are used to compare the qualitative and quantitative characteristics of a person's profile to the requirements of five work environments. The profile qualities considered include a person's:
  - (a) stylistic preferences,
  - (b) the **units of information* used in processing,
  - (c) judgement and decision making tendencies, as well as
  - (d) eight job-related processing dimensions.
- **Learning potential** (the capacity of a person to benefit from instruction)

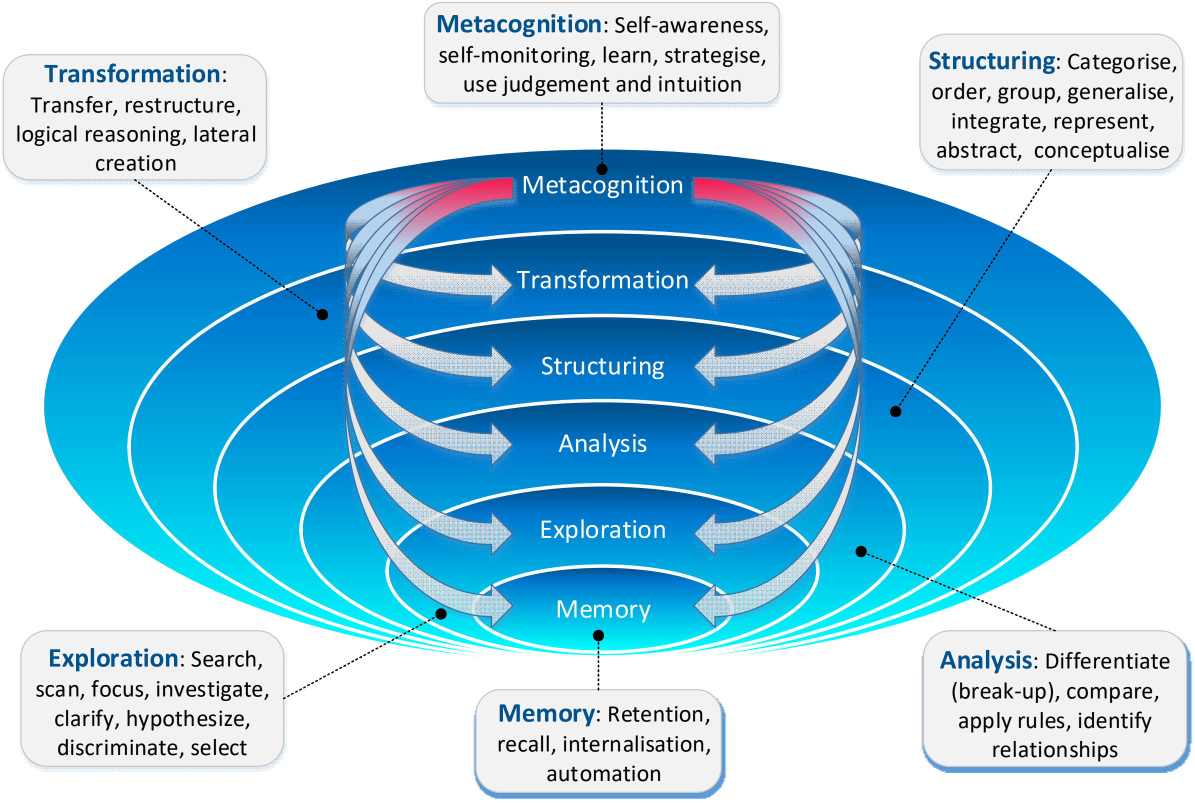
**Units of information* (from the Test Report):
"Individuals tend to focus on specific levels of complexity when dealing with information and when solving problems. Five units of information can be identified from a person's performance to indicate the level of complexity involved, namely:

1. separate elements: a preference for working with tangible and concrete information
2. relationships and linear causality: a preference for working with complete information and previous experience

3. tangible systems: planning and structuring information, coordination of structural elements
4. dynamic and interactive systems: coordinating system information across contexts
5. chaos and emerging patterns: holistic considerations of complex events and implications

These five units of information are linearly related to the five levels of work as reported on by the CPP. "

Figure 2: The cognitive processes assessed by the CPP



The contextualisation of the CPP results in work environments and leadership settings, reflecting the 'levels' concept found in the Stratified Systems Theory (SST) of Elliott Jaques and the Viable Systems Model (VSM) of Stafford Beer.

The CPP assigns an ordered-class 'score' to a respondent, ranging within five 'Levels of Work', for both current and potential Level of Work designations:

1. **Pure Operational**: individuals who show less interest in intellectual complexity, vagueness and cognitive challenge.
2. **Diagnostic**: can be quite analytical, but still show a need for structure in the form of technical guidelines and/or previous experience.
3. **Tactical Strategy**: no longer rely on linear processing, but prefer viewing issues in terms of tangible systems and the interaction between observable system elements.
4. **Parallel Processing**: those with the capacity to accommodate novelty, vagueness, dissonance and fragmentation, all of which require the cognitive skills of integration and innovation.
5. **Pure Strategic**: functioning is characterised by a strong Intuitive and Holistic "big picture" inclination.

From Prinsloo and Barrett (2013, *pp. 1-47)*[1]*:*

> "The SST describes work requirements in terms of a hierarchical structure of increasing complexity and vagueness. The complexity of work, according to Jaques, is best indicated by the time frame involved. The first three levels as specified by the SST show a strong operational focus whereas the fourth and further levels are characterised by a more strategic orientation. In terms of competency requirements, each of the SST levels differs both quantitatively (increasing complexity) and qualitatively (nature of the work) from the other levels.
>
> The CPP does not look at time frame as a criterion of work complexity. Rather, algorithms are used to compare the qualitative and quantitative characteristics of a person's profile to the requirements of five work environments. The profile qualities considered include a person's: (a) stylistic preferences, (b) the units of information used in processing, (c) judgement and decision making tendencies, as well as (d) eight job-related processing dimensions.
>
> The CPP is only linked to the first five levels of the seven level SST model. This can be explained in terms of the cognitive focus of the CPP versus the more holistic nature of the SST model. Potential for Pure Strategic functioning as indicated by the CPP is proposed to be sufficient for cognitive functioning at SST levels 6 and 7. At the highest SST levels, global exposure, leadership characteristics, as well as social and environmental awareness may be required in addition to the cognitive skills and preferences as measured by the CPP".

The construction process of CPP attribute information

- Acquire counts of discrete 'primitive' response-events (e.g. how many times a person turns a particular kind of card in every story)
- Collapse the thousands of primitives into intermediate variables, using *expert-assigned* 'if-then' production rules.
- Collapse the intermediate variables into ~100 summary variables, using *expert-assigned* production rules.
- Collapse the summary variables into 14 styles, 6 processing categories, and 5 levels of work designations.

For example, if the person consistently turns the predictive cards in every story relatively early on in his/her exploration process, followed by the associated rules, then the score on "logical-analytical" as well as "systematic" and "rule oriented", amongst others, increase. The CPP thus looks for processing trends and tendencies and not right and wrong answers.

The micro measurements are then subjected to "if-then" rules for interpretation. This results in a "hierarchy" of approximately a 100 processing scores or categories at different levels of generality. Some of these categories thus are subcomponents of other more inclusive categories. The processing scores thus reflect a layered structure of ever-increasing generality.

Clearly, the CPP attribute construction process is like no other test on the market. The rules for instantiation of the attributes have been constructed by Maretha Prinsloo, and embedded into software to ensure objective implementation. In that sense, the scoring procedure matches that of many other kinds of expert-system application.

[1] Prinsloo, M. & Barrett, P.T. (2013). Cognition: Theory, measurement, implications. *Integral Leadership Review, June.*

In summary, the CPP is an assessment centre/simulation exercise. It assesses attributes using observed performance rather than self-reported performance. "Scoring" is via the objective application of subjective expert-system rules created by the test's author: Maretha Prinsloo. In some respects, the test is similar in scoring concept to Exner's Comprehensive Scoring System for the Rorschach and Meyer et al's Rorschach Performance Assessment System, in that systematic rules are applied to observations in order to establish attribute scores (However, CPP observations are of actual performance rather than cognitive projections).

The MAB (Sigma Assessment Systems Inc.)

From Vernon (2000, p. 195-6)[2]:

> "The Multidimensional Aptitude Battery (MAB; Jackson, 1984) is a multiple-choice, group-administrable test of intelligence patterned quite closely after the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981). Like the WAIS-R, the MAB consists of two subscales, Verbal and Performance, each comprising five subtests. The MAB is designed to be used with adolescents and adults between 16 and 74 years of age and is scored to provide Verbal, Performance, and Full-Scale IQs as well as subtest profiles.
>
> In the **Verbal Scale**, subtests include *Information* (a 40-item test of general knowledge), *Comprehension* (a 28-item test measuring a person's understanding of various social situations or conventions); *Arithmetic* (26 items ranging in difficulty from simple arithmetic to complex numerical reasoning); *Similarities* (a 34-item test in which people must decide in what way two things are alike); and *Vocabulary* (46 items). Each of these subtests taps the same constructs as those in the WAIS-R, though all of the actual items are different. Note also that there is no MAB subtest comparable to the WAIS-R's Digit Span.
>
> In the **Performance Scale**, the MAB subtests include *Digit Symbol* (a 35-item test in which the digits 1 to 9 are matched [or coded] with different symbols. Subjects are presented with strings of from 1 to 9 symbols and must identify which of five accompanying strings of digits correctly matches the symbols); *Picture Completion* (35 items in which pictures of objects with one missing part are presented. Accompanying each picture are the first letters of five possible missing parts. Subjects must first identify the correct missing part in each picture and then choose its first letter correctly from among the distractors); *Spatial* (a 50-item test in which subjects must spatially rotate a figure and match the rotation to one of five possible answers. This is the only MAB subtest that does not have a precise counterpart in the WAIS-R; it is the MAB's alternative to the WAIS-R's Block Design); *Picture Arrangement* (21 items in which subjects must mentally rearrange between 3 and 6 cartoon panels to tell a sensible story); and *Object Assembly* (a 20-item test in which between 3 and 6 numbered silhouetted parts of common objects are presented in the wrong order. Subjects must first identify the objects and then mentally rearrange their parts into the correct order).
>
> Internal consistency reliability coefficients are reported in the MAB Manual (Jackson, 1984) for each of its subtests and for Verbal, Performance, and Full-Scale IQ scores {FSIQ}. Subtest reliabilities range from .70 to . 96 and VIQ, PIQ, and FSIQ reliabilities range from .94 to .98 in different age groups. Test-retest stability and split-half reliability coefficients are also reported in the MAB Manual: subtest stability coefficients range from .83 to .97, VIQ, PIQ, and FSIQ stability coefficients are .95, .96, and .97, respectively; subtest split-half reliabilities (Spearman-Brown corrected) range from .55 to .87, VIQ, PIQ, and FSIQ corrected reliabilities are .92, .94, and .95. Clearly, the MAB Scale scores are highly reliable and the reliabilities of its individual subtests are at least satisfactory."

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[2] Vernon, P.A. (2000). Recent studies of intelligence and personality Using Jackson's Multidimensional Aptitude Battery and Personality Research Form. In R.D. Goffin & E. Helmes (Eds.). *Problems and Solutions in Human Assessment: Honoring Douglas N. Jackson at Seventy* (pp. 195-212). Boston, MA: Springer. ISBN: 9781-4613-6978-3.

Age-Corrected Scaled Scores (standardized/normalized) for the subtests, and prorated Age-Corrected Full-Scale IQ scores were used for all subsequent data analyses.

Assessment Procedure

Respondents were assessed on the CPP and MAB under proctored conditions. Because of specific language and cultural concerns (many potential respondents did not always possess the same educational exposure to words, phrases, and information content which are common to many European and North American countries), and time constraints on assessment, not all MAB subtests were used in this study. In fact only four out of 10 were used:

- Comprehension
- Similarities
- Picture Arrangement
- Object Assembly

This meant that Verbal, Performance, and Full-Scale IQ would be prorated estimates.

The CPP was always administered via computer, as it can only be administered this way. The MAB was sometimes administered via computer in a group setting (using a university computer lab), but mostly via paper and pencil. The CPP was completed by all respondents prior to them being administered the MAB. But never in the same session as CPP completion could take up to 2½hrs. The CPP is an open-ended-duration assessment unlike the MAB where each subtest is a fixed 7 minutes duration.

Scoring for the CPP was always via computer. Likewise the MAB, using either computer-based scoring of the computer-generated test files, or key-to-disc from answer-sheets.

Results

1.1 Descriptive Statistics

The descriptive statistics of the MAB subscales and full-scale IQ variables are provided in Table 2 below.

Table 2: MAB descriptive statistics (SA sample)

	South African dataset							
Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
Comprehension	161	43.81	44	23	63	38	50	8.364
Similarities	160	51.87	53	28	67	47	58	8.073
Picture Arrangement	161	43.58	43	24	68	37	50	8.592
Object Assembly	161	48.73	49	30	93	42	54	9.405
Verbal IQ	160	97.28	98	67	126	88	106	12.113
Performance IQ	161	94.78	94	65	140	84	105	14.673
Full Scale IQ	160	95.89	94	68	128	87	106	12.851

For comparison purposes, the same statistics are computed from a dataset of 224 female and 82 male volunteer adults who completed the MAB under group administered/proctored conditions, as part of ongoing research into biological and chronometric correlates of ability.[3] Tables 3 and 5 provide the comparative data.

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[3] Barrett, P.T. and Eysenck, H.J. (1994). The relationship between evoked potential component amplitude, latency, contour length, variability, zero crossings, and psychometric intelligence. *Personality and Individual Differences*, 16, 1, 3-32.

Table 3: MAB descriptive statistics (UK Biosignal Lab sample)

Variable	Descriptive Statistics - UK Biosignal Lab MAB IQ data Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
Comprehension	307	56.45	58	28	68	53	62	7.309
Similarities	307	57.89	59	18	75	52	66	9.790
Picture Arrangement	307	54.92	56	22	76	50	60	8.849
Object Assembly	306	54.26	55	32	73	48	62	8.740
Verbal IQ	307	110.47	111	72	137	103	119	12.207
Performance IQ	307	108.45	110	63	137	100	118	13.228
Full Scale IQ	307	109.68	111	67	136	102	118	11.780

Table 4: MAB subscale and full-scale Pearson correlations (SA sample)

Variable	South African Dataset, N=160, Pearson correlations Comprehension	Similarities	Picture Arrangement	Object Assembly	Verbal IQ	Performance IQ	Full Scale IQ
Comprehension	1.00	0.76	0.55	0.46	0.74	0.47	0.67
Similarities	0.76	1.00	0.53	0.43	0.73	0.42	0.64
Picture Arrangement	0.55	0.53	1.00	0.59	0.47	0.76	0.69
Object Assembly	0.46	0.43	0.59	1.00	0.38	0.72	0.63
Verbal IQ	0.74	0.73	0.47	0.38	1.00	0.62	0.89
Performance IQ	0.47	0.42	0.76	0.72	0.62	1.00	0.91
Full Scale IQ	0.67	0.64	0.69	0.63	0.89	0.91	1.00

Table 5: MAB subscale and full-scale Pearson correlations (UK Biosignal Lab sample)

Variable	UK Biosignal LAB (1994), N=306, Pearson correlations Comprehension	Similarities	Picture Arrangement	Object Assembly	Verbal IQ	Performance IQ	Full Scale IQ
Comprehension	1.00	0.69	0.51	0.39	0.82	0.56	0.76
Similarities	0.69	1.00	0.50	0.44	0.85	0.58	0.79
Picture Arrangement	0.51	0.50	1.00	0.55	0.52	0.76	0.69
Object Assembly	0.39	0.44	0.55	1.00	0.51	0.84	0.73
Verbal IQ	0.82	0.85	0.52	0.51	1.00	0.67	0.92
Performance IQ	0.56	0.58	0.76	0.84	0.67	1.00	0.90
Full Scale IQ	0.76	0.79	0.69	0.73	0.92	0.90	1.00

As can be seen from Tables 4 and 5, the monotonic relationship between IQ variables is very similar between both the South African and UK datasets.

With regard to correlating CPP attributes with MAB ability scale scores, there are 78 component attributes contributing to the CPP report (some directly, some indirectly). All have been transformed into a unitary T-score metric based upon the normative CPP dataset of over 80,000 cases, where fixed upper and lower score-bounds are between 0 and 100.

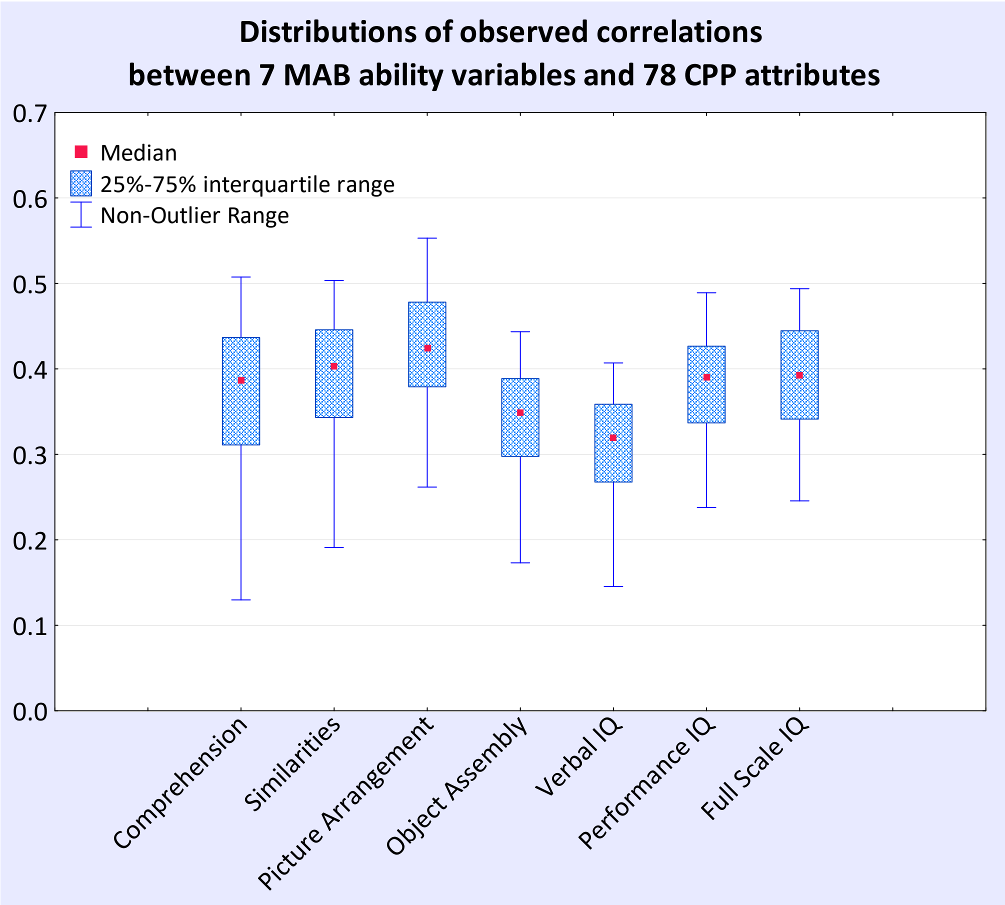
If I were to correlate all 7 MAB variables with each of the 78 CPP variables, I would need to compute and display 546 discrete correlations. This is neither useful nor sensible. Rather, to get a good feel for the patterning of correlations among the ability and CPP scales, I instead plotted the varying correlations for the CPP attributes for each MAB ability scale, as a median/inter-quartile range box-plot. In this way, one can easily view the overall density of correlation magnitudes. Table 6 provides the list of CPP attributes, and Figure 3 the boxplot of relationships.

1.2 Correlations and Structural Relations

Table 6: the 78 CPP T-score attributes

CPP Variable	Description	CPP Variable	Description
T-score_0	Number of card movements	T-score_40	Analytical style
T-score_1	Focus on obvious clues	T-score_42	Formulating hypothesis
T-score_2	Focusing on internal clues	T-score_43	Exploring
T-score_3	Discrimination	T-score_44	Aspects of learning
T-score_4	General approach	T-score_45	Quick disclosure
T-score_5	Exploration	T-score_46	Making assumptions
T-score_6	Meta-cognitive directing of exploration	T-score_48	Quick insight
T-score_7	Differentiation	T-score_49	Elimination strategy
T-score_8	Analytical identification of relationships	T-score_50	Carefully applying instructions
T-score_9	Comparative spontaneity	T-score_51	Adapted memory score
T-score_10	Rule orientation	T-score_52	Gradual improvement learning
T-score_11	Precision and systematic approach	T-score_54	Judgement to clarify fuzzy information
T-score_12	Meta-cognitive monitoring of analytical behaviour	T-score_55	Logical reasoning
T-score_13	External ordering and categorizing of information	T-score_56	Speed
T-score_15	Quick insight learning	T-score_57	Repeated checking
T-score_16	Coherence in conceptual	T-score_58	Adjusted complexity score
T-score_17	Degree of detail	T-score_59	Adjusted quick insight
T-score_18	Systemic approach	T-score_61	Explorative style
T-score_19	Integrate discrepant information	T-score_62	Analytical style
T-score_20	Complexity	T-score_63	Structured style
T-score_21	Formulating analogies and metaphors	T-score_64	Holistic style
T-score_22	Generalization	T-score_65	Intuitive style
T-score_23	Extracting core elements	T-score_66	Memory style
T-score_24	Story telling	T-score_67	Logical style
T-score_25	Strategies to order and structure information	T-score_68	Impulsive style
T-score_26	Follows arguments through	T-score_69	Random style
T-score_27	Generating abstract unusual concepts	T-score_70	Integrative style
T-score_28	Cognitive flexibility	T-score_71	Systems style
T-score_29	Logical proof	T-score_72	Learning style
T-score_30	Meta-cognitive strategies for logical reasoning	T-score_73	Quick insight style
T-score_31	Relying on own memory	T-score_74	Reflective style
T-score_32	Memory strategies	T-score_75	Metaphoric style
T-score_33	Economy and effectiveness of approach	T-score_91	Focusing and selecting relevant information
T-score_34	Awareness and alertness	T-score_92	Linking detailed relationships
T-score_35	Task and goal orientation	T-score_93	Structuring information
T-score_36	Self-monitoring	T-score_94	Transforming information
T-score_37	Strategizing	T-score_95	Overall memory
T-score_38	Strategies to deal with complexity	T-score_96	Meta-cognitive awareness
T-score_39	Pace control	T-score_99	Average score

Figure 3: The distribution of observed Pearson correlations between CPP attributes and MAB ability scales (n=149, casewise)



As can be seen from this graph, there is a modest relationship between ability/ IQ and the CPP variables. The majority of correlations between ability and CPP attributes are below 0.4.

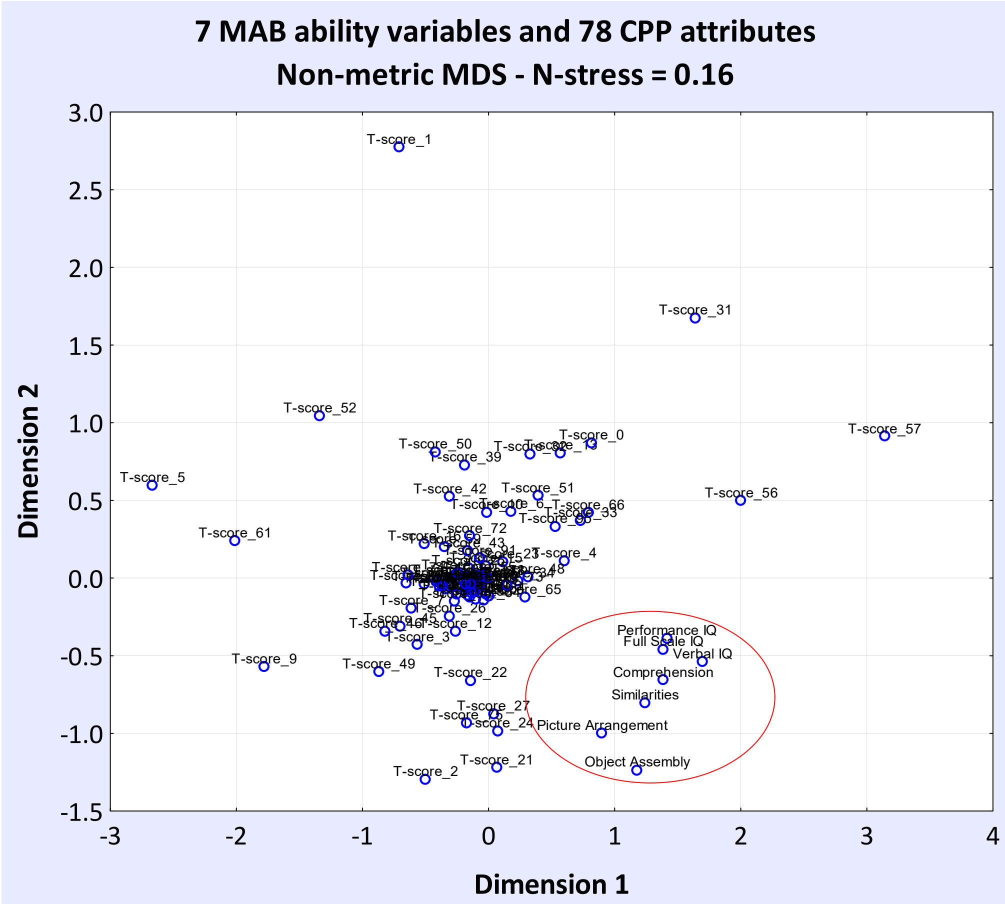
In order to show graphically the relationship between ability variables and the CPP attributes, a non-metric Guttman-Lingoes smallest space analysis (non-metric multidimensional scaling) was undertaken using all 78 CPP attributes and the 7 MAB ability variables.

Pearson correlations were used as the input 'distance' coefficients, computed over 149 complete cases of data. A 2-dimensional solution was considered acceptable, with normalized stress[4] of 0.16.

Figure 4 shows the 2-dimensional map of all the attributes.

[4] Normalized stress *(the Kruskal/Stressform1 version*) indexes the disparity between the observed variable distances minus their monotone regressed 'pseudo-distances'. The square root is taken of the result of dividing the sum of squared {observed distances– model-constructed distances} by the sum of squared actual distances. It varies between 0 and a maximum if (1-(2/p)) where p= the number of variables, and where 0 = perfect recovery of inter-variable distances. A value > 0.2 is conventionally taken as indicative of unacceptable fit, although as Borg and Groenen point out (pp. 337-38), this should not be used as a precise threshold (Borg, I., & Groenen, P. (1997). Modern Multidimensional Scaling: Theory and Applications. Springer. ISBN: 0-387-94845-7).

Figure 4: A non-metric multidimensional scaling (MDS) 2-D solution for 78 CPP and 7 MAB ability variables

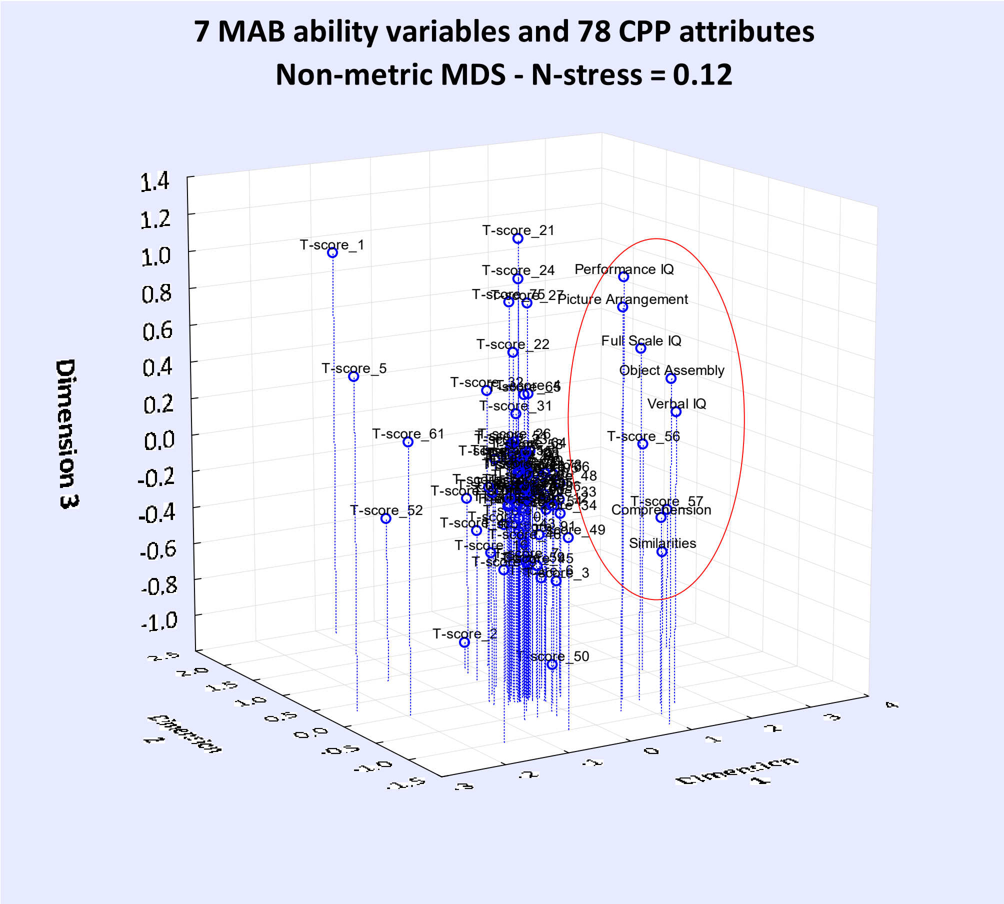


Two regions of interest are apparent in this figure:

1. Many of the CPP T-scores are highly related to one another, indicating a level of redundancy within the CPP attribute-set.
2. The ability variables form a distinct cluster from the CPP attributes (circled in red for convenience).

In order to establish whether the same 'discreteness' was present if I allowed the solution to 'expand' into 3-dimenional space, I recomputed the MDS solution accordingly. The 3-D solution showed a normalized stress value of **0.12**.

Figure 5: A non-metric multidimensional scaling (MDS) 3-D solution for 78 CPP and 7 MAB ability variables



The same two regions of interest are apparent in this figure:

1. Many of the CPP T-scores are highly related to one another, indicating a level of redundancy within the CPP attribute-set.
2. The ability variables form a distinct cluster from the CPP attributes (circled in red).

1.3 CPP Intellectual Styles and MAB Ability Correlations

Focusing on the 15 intellectual styles (T-scores 61 to 75), the Pearson correlations between these and the MAB scales are presented in Table 7.

Table 7: The Pearson correlations between the CPP intellectual styles and MAB ability scales (n=149, casewise)

	CPP Intellectual styles vs MAB Ability scales						
Variable	Comprehension	Similarities	Picture Arrangement	Object Assembly	Verbal IQ	Performance IQ	Full Scale IQ
T-score_61: CPP: Explorative style	0.01	0.05	0.17	0.08	-0.02	0.10	0.05
T-score_62: CPP: Analytical style	0.34	0.39	0.40	0.35	0.26	0.35	0.35
T-score_63: CPP: Structured style	0.38	0.43	0.44	0.36	0.32	0.40	0.41
T-score_64: CPP: Holistic style	0.45	0.44	0.51	0.37	0.36	0.45	0.45
T-score_65: CPP: Intuitive style	0.49	0.44	0.55	0.38	0.40	0.48	0.49
T-score_66: CPP: Memory style	0.47	0.42	0.40	0.39	0.38	0.41	0.45
T-score_67: CPP: Logical style	0.39	0.43	0.45	0.33	0.31	0.38	0.39
T-score_68: CPP: Impulsive style	-0.29	-0.36	-0.37	-0.33	-0.25	-0.35	-0.34
T-score_69: CPP: Random style	-0.46	-0.47	-0.48	-0.39	-0.37	-0.42	-0.45
T-score_70: CPP: Integrative style	0.44	0.44	0.49	0.38	0.37	0.45	0.46
T-score_71: CPP: Systems style	0.44	0.45	0.50	0.39	0.38	0.46	0.47
T-score_72: CPP: Learning style	0.36	0.38	0.45	0.35	0.32	0.41	0.41
T-score_73: CPP: Quick insight style	0.51	0.50	0.55	0.41	0.41	0.47	0.49
T-score_74: CPP: Reflective style	0.24	0.30	0.36	0.26	0.19	0.30	0.27
T-score_75: CPP: Metaphoric style	0.27	0.29	0.40	0.28	0.26	0.36	0.35

Small to moderate relationships are seen throughout this matrix. Correlations above **0.16** are significant at p < 0.05, two-tail.

1.4 CPP Levels of Work and MAB Ability Relationships

In terms of the CPP's Level of Work designation:

1. **Pure Operational**: individuals who show less interest in intellectual complexity, vagueness and cognitive challenge.
2. **Diagnostic**: can be quite analytical, but still show a need for structure in the form of technical guidelines and/or previous experience.
3. **Tactical Strategy**: no longer rely on linear processing, but prefer viewing issues in terms of tangible systems and the interaction between observable system elements.
4. **Parallel Processing**: those with the capacity to accommodate novelty, vagueness, dissonance and fragmentation, all of which require the cognitive skills of integration and innovation.
5. **Pure Strategic**: functioning is characterised by a strong Intuitive and Holistic "big picture" inclination.

The observed range of the Level of Work attributes was {1..4}, for both current and potential designations. Given the Levels of Work are clearly ordered-class attributes, Kruskal gamma correlations were computed between the two CPP Level of Work attributes and MAB ability scales.

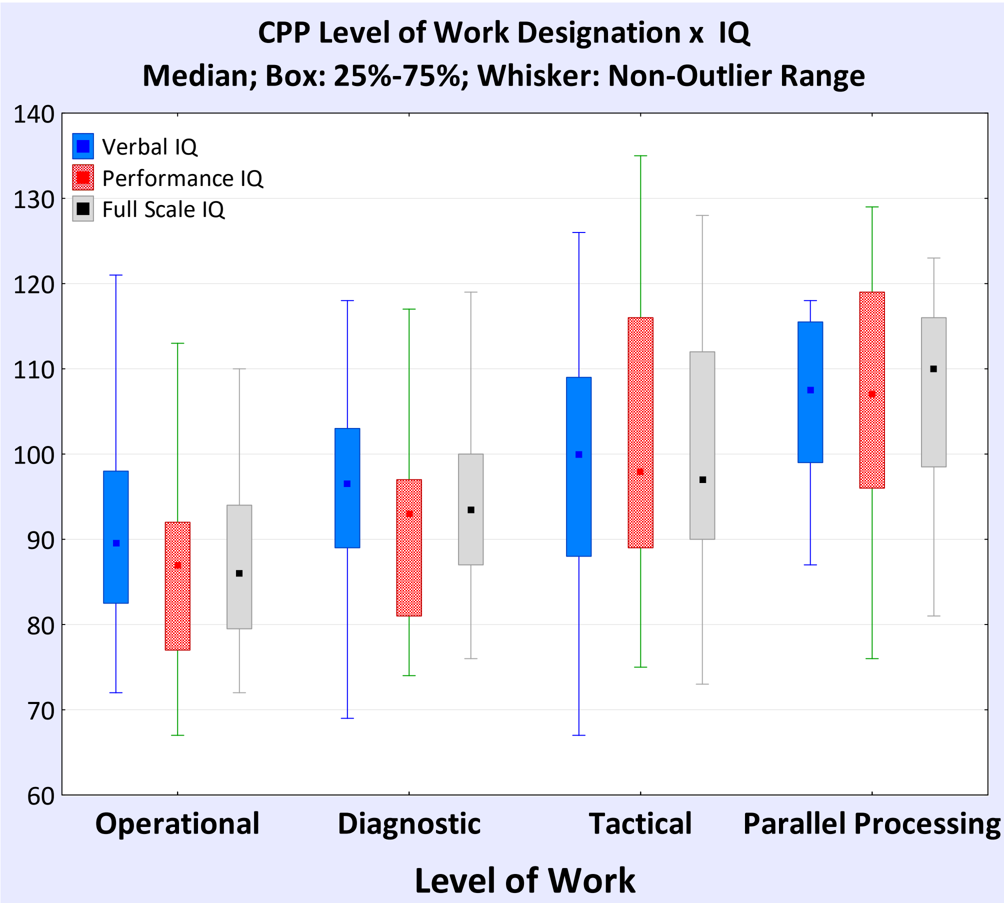
Table 8: Gamma correlations between the CPP Levels of Work attributes and the MAB ability scales.

Variable	CPP Levels of Work x MAB ability scales Kruskal gamma correlations	
	Level of Work	Potential Level of Work
Comprehension	0.47	0.40
Similarities	0.45	0.42
Picture Arrangement	0.49	0.41
Object Assembly	0.46	0.33
Verbal IQ	0.34	0.34
Performance IQ	0.41	0.34
Full Scale IQ	0.41	0.37

The number of cases for the Comprehension, Picture Arrangement, Object Assembly, and Performance IQ correlations is 150, the remaining correlations were calculated over 149 cases. All are statistically significant at $p < 0.01$ two-tail.

In terms of the actual MAB ability score levels and variability associated with each current Level of Work designation, a box-plot was generated showing the full-scale IQ variable characteristics as a function of Level of Work.

Figure 6: CPP Level of Work designation x MAB full-scale IQ variables

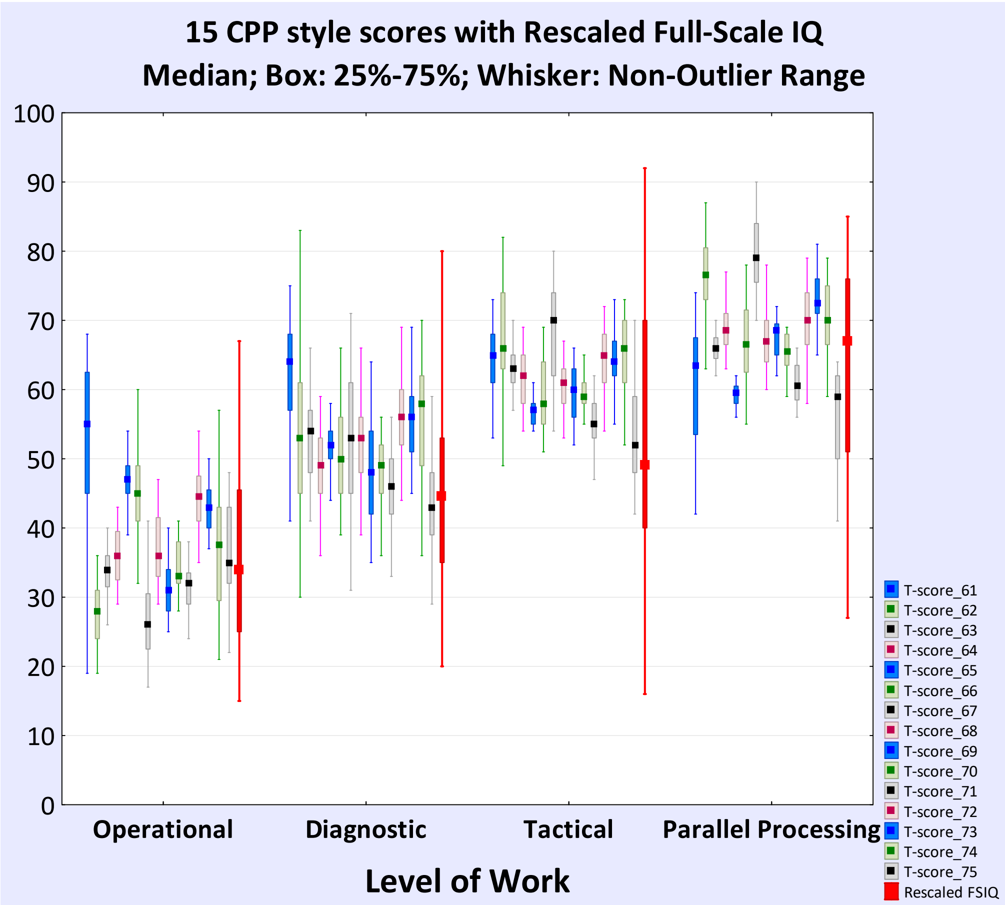


For each ability variable, there is a monotonic relationship between median IQ and Level of Work designation. But, there is also considerable overlapping variation between levels, indicating that Level of Work is not simply a proxy for ability, but contains substantive individual difference information beyond cognitive ability.

1.5 CPP Intellectual Styles and MAB Ability Scales Structural Relations

We can further explore this monotonic relationship by plotting the variability in MAB full-scale IQ alongside the variability in CPP intellectual style scores, as a function of Current Level of Work designation. In order to express MAB IQ scores in the metric of the Intellectual style scores, common metric rescaling (see Appendix 1) was undertaken on the MAB IQ scores, where a 65-130 range MAB Full-scale IQ was linearly re-expressed within the typical T-score range of 5 to 95.

Figure 7: CPP intellectual style scores plotted with rescaled MAB full-scale IQ

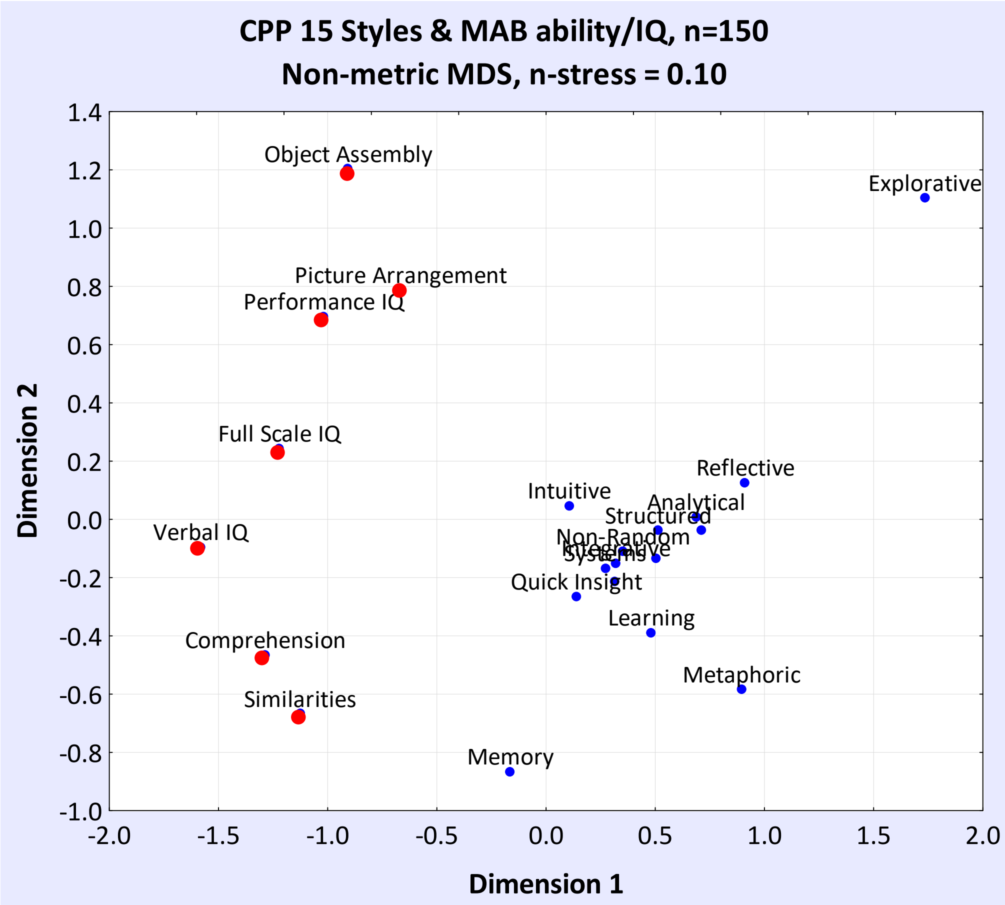


The monotonic trend with IQ is apparent, but there is sufficient substantive variability in both style scores and IQ to conclude they are not meaningfully equivalent to one another.

To further show the separability between the CPP intellectual styles and the MAB ability scales, a 2-dimensional non-metric MDS was undertaken on the 15 style scores + 7 MAB ability scale scores. Initial variable distances were computed using the Gower[5] agreement coefficient (expressed as similarities). A 2-dimensional solution indicated a normalized stress value of 0.10.

[5] Gower, J.C. (1971). A general coefficient of similarity and some of its properties. Biometrics, 27, 857-874.

Figure 8: Non-metric MDS of 15 CPP intellectual style scores and 7 MAB ability scales



As in Figure 4 on page 14, the MAB ability scales tend to show some separability from the CPP attributes.

In Conclusion

While the CPP attributes are clearly related to MAB abilities, the various analyses conducted show that there is substantive information assessed by the CPP which is not assessed by the MAB. From a theoretical perspective, this is just about right as the CPP would be expected to engage an individual's cognitive abilities, but not to the extent that performance on the CPP was a direct function of those abilities.

Study 2: The Cognitive Process Profile (CPP) & Psytech International General Reasoning Test Battery (GRT2)

Aim: to explore the relationships between attributes assessed by the CPP and the abstract-reasoning subscale of the GRT2.

Sample: 259 South African employment candidates assessed within a recruitment process by an organizational development consultancy. Gender and age were not recorded in the dataset provided to us. 143 cases completed the CPP, with 138 cases with complete data on both the CPP and GRT2 Abstract.

Assessments

The CPP

Full details provided in Study 1.

The GRT2

From the product website:
http://www.psytech.com/psytech-assessments/aptitude-ability/general-reasoning-test/

> "A comprehensive and in-depth measure of mental agility, GRT2 has been designed to assess general reasoning ability. Suitable for non-graduate level applicants, it consists of three sections which can be administered individually or together, measuring Verbal, Numerical and Abstract reasoning ability.
>
> The **Abstract Reasoning** scale measures the ability to understand abstract logical problems and use new information outside the range of previous experience. This is the purest form of mental ability and is least affected by previous education and achievement. It is therefore ideally suited to assess individuals of various educational backgrounds and cultural groups"

Completion time for the Abstract subscale is 10 minutes (it's a timed test), with number-correct score-range between 0 and 25 (p. 18, GRT2 Technical manual).

Results

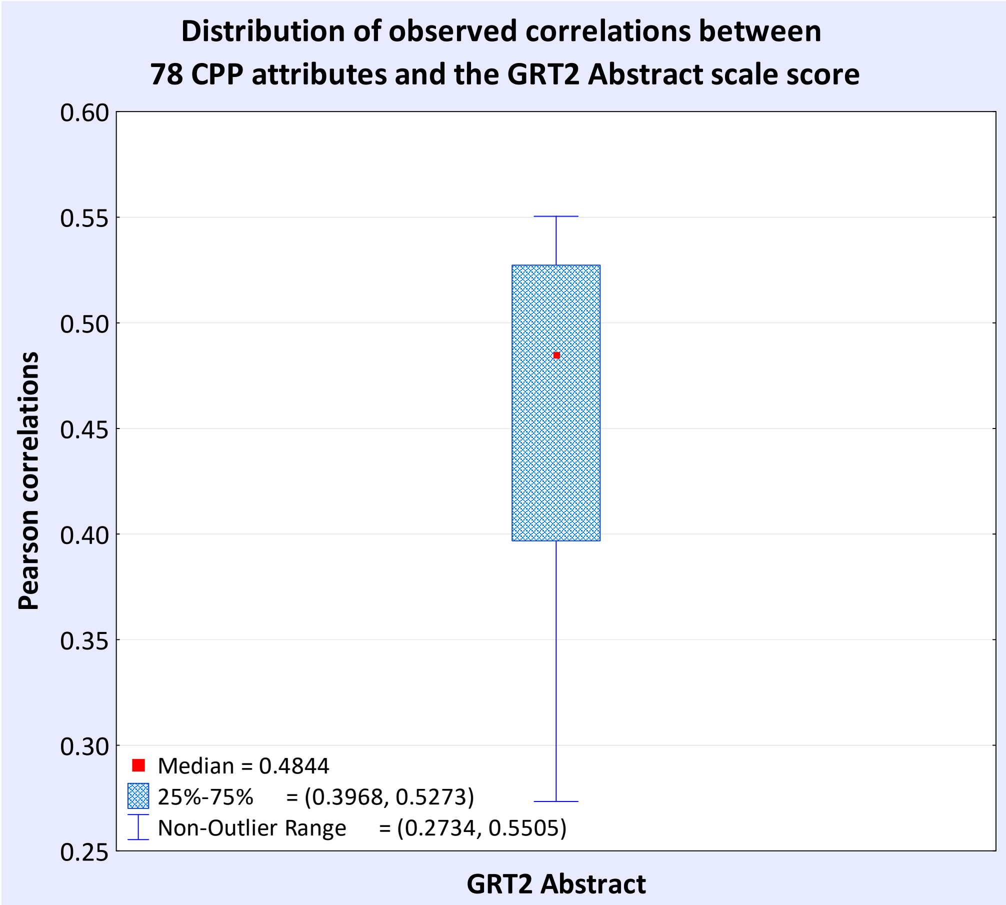
2.1 Descriptive Statistics and Correlations

Table 9: Descriptive statistics of the GRT2 Abstract reasoning scores

	Candidates - Organization Consultancy (SA)							
Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
GRT2 Abstract	259	13.97	14	2	24	10	18	4.981

As before (for the MAB), I plotted the varying Pearson correlations for the CPP attributes with the Abstract scale scores as a median/inter-quartile-range box-plot. In this way, one can easily view the overall density of correlation magnitudes. Table 6 (p.13) provides the list of CPP attributes, and Figure 3 (p. 14) the boxplot of MAB relationships. Table 10 provides the boxplot for the CPP x GRT2 correlations.

Figure 9: Boxplot of the 78 CPP attribute correlations with the GRT2 Abstract Reasoning scale (n=138)



As expected, a similar result to that shown in Figure 3 (p. 14) was observed, although in this case the median correlation is slightly higher at 0.48. In terms of the CPP Intellectual styles, the correlations between these and the GRT2 Abstract scale scores are:

Table 10: Correlations between the CPP Intellectual Style scores and GRT2 Abstract scores

	Candidates - Organization Consultancy (SA) Psytech GRT2: n = 138 cases
Variable	GRT2 Abstract
T-score_61: CPP: Explorative style	0.19
T-score_62: CPP: Analytical style	0.53
T-score_63: CPP: Structured style	0.54
T-score_64: CPP: Holistic style	0.53
T-score_65: CPP: Intuitive style	0.46
T-score_66: CPP: Memory style	0.40
T-score_67: CPP: Logical style	0.55
T-score_68: CPP: Impulsive style	-0.53
T-score_69: CPP: Random style	-0.54
T-score_70: CPP: Integrative style	0.54
T-score_71: CPP: Systems style	0.51
T-score_72: CPP: Learning style	0.50
T-score_73: CPP: Quick insight style	0.49
T-score_74: CPP: Reflective style	0.51
T-score_75: CPP: Metaphoric style	0.33

* Note: I've not reversed the T-scores for Impulsive and Random style, which is why they show a negative relationship with GRT2 Abstract.

For the CPP Current and Potential Level of Work attributes, the frequencies of designations were:

Table 11: Frequencies of designations for CPP current Level of Work

Category	Candidates - Organization Consultancy (SA) Current Level of Work			
	Count	Cumulative Count	Percent	Cumulative Percent
1	16	16	11.19	11.19
2	68	84	47.55	58.74
3	36	120	25.17	83.92
4	23	143	16.08	100.00

Table 12: Frequencies of designations for CPP potential Level of Work

Category	Candidates - Organization Consultancy (SA) Potential Level of Work			
	Count	Cumulative Count	Percent	Cumulative Percent
1	7	7	4.90	4.90
2	41	48	28.67	33.57
3	36	84	25.17	58.74
4	59	143	41.26	100.00

Table 13: Gamma correlations between current and potential Level of Work and GRT2 scores

Variable	Gamma Correlations between GRT2 and CPP Level of Work attributes n = 138
	GRT2 Abstract
Level of Work	0.49
Potential Level of Work	0.51

In Conclusion

Very similar results to those of the MAB. Moderate relationships among many CPP attributes and GRT2 Abstract reasoning, but a substantive degree of variation in CPP scores not accounted for by the GRT2 Abstract scores.

Study 3: The Cognitive Process Profile (CPP) & Psytech International Critical Reasoning Test Battery (CRTB2)

Aim: to explore the relationships between attributes assessed by the CPP and the numerical and verbal critical reasoning subscales of the CRBT2.

Sample: 128 South African employment candidates assessed within a recruitment process by an HR consultancy. Gender and age were not recorded in the dataset provided to us.

Assessments

The CPP

Full details provided in Study 1. For this dataset, only scores from 14 CPP information processing competencies and the 2 Levels of Work attributes were available for analysis.

The CRTB2

From the product website:
http://www.psytech.com/psytech-assessments/aptitude-ability/critical-reasoniong-tes/

> "Critical Reasoning is an ability that is central to all roles that require the incumbent to take logical decisions based on complex information. CRTB2 has been developed to this core ability in a time and cost effective manner. CRTB2 comprises two sub-tests which measure verbal and numerical critical reasoning. These can be administered either individually or together.
>
> **Verbal Critical Reasoning** measures the ability to understand and accurately draw logical conclusions and inferences from complex reports. Consequently, it forms a key assessment for managerial and professional roles which require accurate interpretation of written reports and rational decision making.
>
> **Numerical Critical Reasoning** measures the ability to understand and critically evaluate a wide range of numerical data and draw logical conclusions from this. Consequently, it forms a key assessment for managerial and professional roles which require the ability to understand financial, numerical and statistical information."

Completion time for the Verbal subscale is 15 minutes (the CRTB2 is a timed test), with number-correct score-range between 0 and 40 (p. 32, CRBT2 Technical manual). Completion time for the Numerical subscale is 25 minutes, with number-correct score-range between 0 and 25 (p. 35, CRBT2 Technical manual).

Results

3.1 Descriptive Statistics and Correlations

Table 14: Descriptive statistics for the CRTB2 Numerical and Verbal critical reasoning scales

	Candidates - HR Consultancy (SA)							
Variable	Valid N	Mean	Median	Minimum	Maximum	Lower Quartile	Upper Quartile	Std.Dev.
CRTB2-Numerical	128	11.95	12	1.0	25	9	15	4.727
CRBT2-Verbal	128	15.96	15	1.0	33	12	20	6.391

Figure 10 provides a box-plot of the 14 CPP information-processing attribute scores.

Figure 10: Boxplot (median and interquartile range) of the 14 CPP information processing attributes

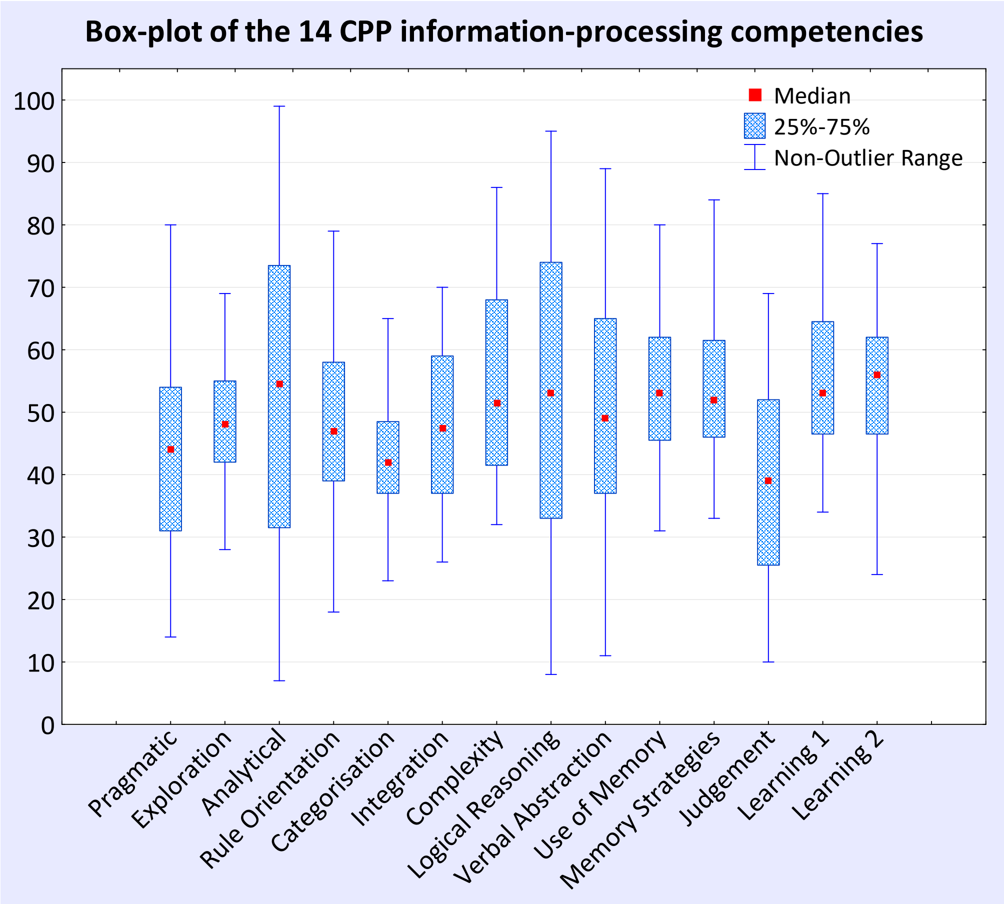


Table 15 provides the Pearson correlations for 14 CPP information processing competencies and the two CRTB2 scale scores.

Table 15: Correlations between 14 CPP information-processing competencies and the CRTB2 Numerical and Verbal critical reasoning scales

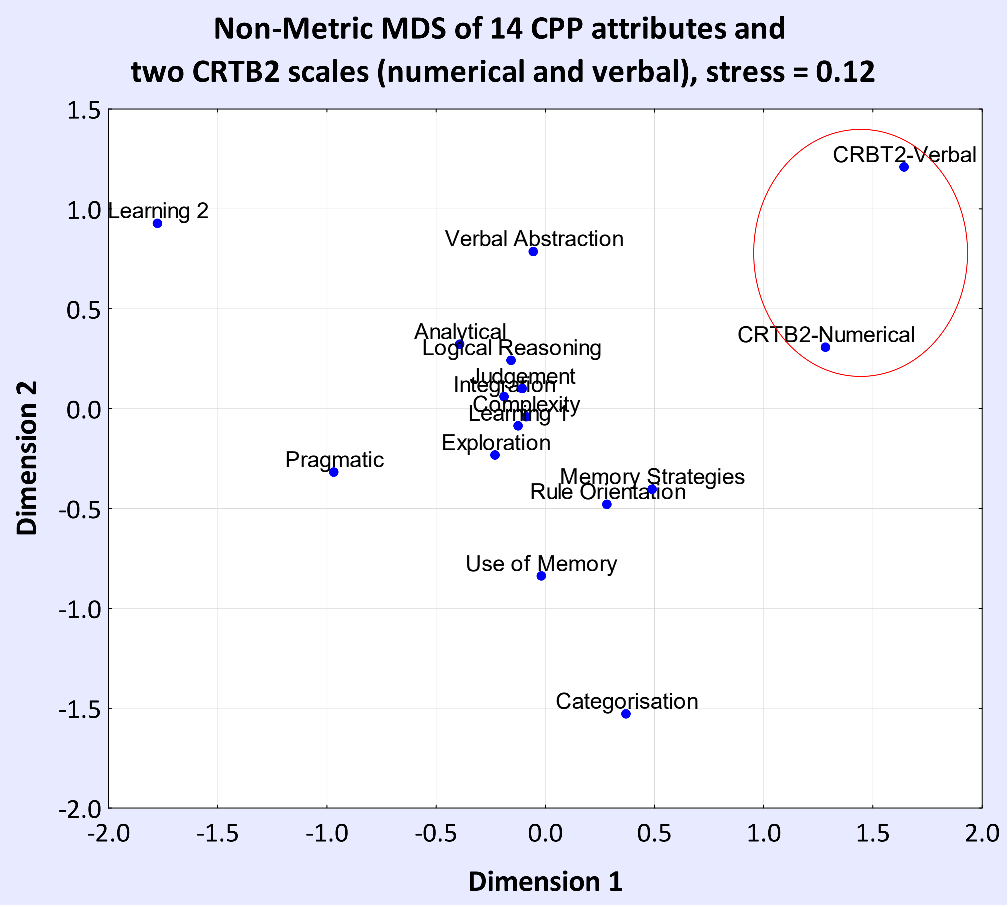
	HR consultancy candidates (SA) n=128	
Variable	CRTB2-Numerical	CRBT2-Verbal
Pragmatic	0.42	0.26
Exploration	0.56	0.44
Analytical	0.57	0.41
Rule Orientation	0.60	0.44
Categorisation	0.47	0.33
Integration	0.64	0.50
Complexity	0.63	0.48
Logical Reasoning	0.58	0.41
Verbal Abstraction	0.54	0.41
Use of Memory	0.48	0.43
Memory Strategies	0.59	0.52
Judgement	0.64	0.49
Learning 1	0.62	0.50
Learning 2	0.37	0.27

Table 16: Gamma correlations between current and potential Level of Work and CRTB2 Numerical and Verbal scores

Variable	Gamma correlations - HR consultancy candidates (SA) n=128	
	CRTB2-Numerical	CRBT2-Verbal
Level of Work	0.62	0.48
Potential Level of Work	0.60	0.37

A non-metric MDS was undertaken on the CPP information processing competencies and the two CRTB2 critical reasoning scales; input coefficients were Pearson correlations. A 2-dimensional solution was selected with a normalized stress of 0.12.

Figure 11: Non-metric MDS of the CPP information-processing competencies and CRTB2 numerical and verbal scales



The two CRTB2 scales are located in a semi-discrete region of the 2-D space, indicating some degree of separability between the CRTB2 attributes and the CPP information-processing competencies.

In Conclusion

Very similar results to those of the MAB and GRT2, with moderate relationships among 14 CPP information processing attributes and the CRTB2 numerical and verbal critical reasoning scores. Interestingly, the numerical critical reasoning scale scores showed a higher median correlation with the CPP attributes than did the verbal scale; 0.58 vs 0.43 respectively.

Appendix 1: Common Metric Rescaling

When wanting to display and compare data from variables whose measurement metric is not the same, it is useful to rescale each variable's values into a convenient common metric. This is especially the case when displaying data with different ranges in multiple line-graphs and scatterplots, and for comparing multiple variables with coefficients such as the Gower agreement index.

Also, with specific regard to the Gower and other relative magnitude agreement indices, using two variable vectors with differing minimum and maximum values produces incorrect agreement measures because the relative change in one variable vector is not equal to the relative change in another *(because of the inequality which exists between the respective minima and maxima)*.

Unlike conventional standardization, which transforms a variable's values by subtracting each observed value from the mean of all observed values and dividing this difference by the standard deviation of the values, the rescaling implemented here preserves the relativity between each variables' observations while rescaling the raw magnitudes into a common metric.

For example, displayed in the table 17 below are two vectors of data, for hypothetical Short **(0-20)** and Long **(0-60)** scale scores:

Table 17: Example dataset for demonstrating the common-metric-rescaling computations

	Example spreadsheet - Short vs Long scores	
	1 Short	2 Long
1	4	23
2	2	11
3	6	26
4	12	43
5	6	16
6	5	13
7	3	10
8	7	33
9	16	50
10	7	23
11	14	23
12	12	50
13	6	34
14	9	49
15	6	33
16	2	10
17	8	40
18	3	10
19	5	15
20	1	10

Clearly, the raw score magnitudes are very different in magnitude to one another. The correlation between them however is 0.79, reflecting the *monotonic* agreement between the scores.

The raw data are plotted in Figure 12. The score relationship as a result of standardization can be seen in Figure 13. The result of the common metric rescaling of the Long-Form scores so as to express them in the same metric as the short-form scores (0-20) is shown in Figure 14.

The distortion of the scale score relative magnitudes caused by standardization can be seen in Figure 13, contrasted with the purely linear equating in Figure 14. There is no excuse for standardizing data if the goal is to compare agreement or indeed magnitude differences between two vectors of data.

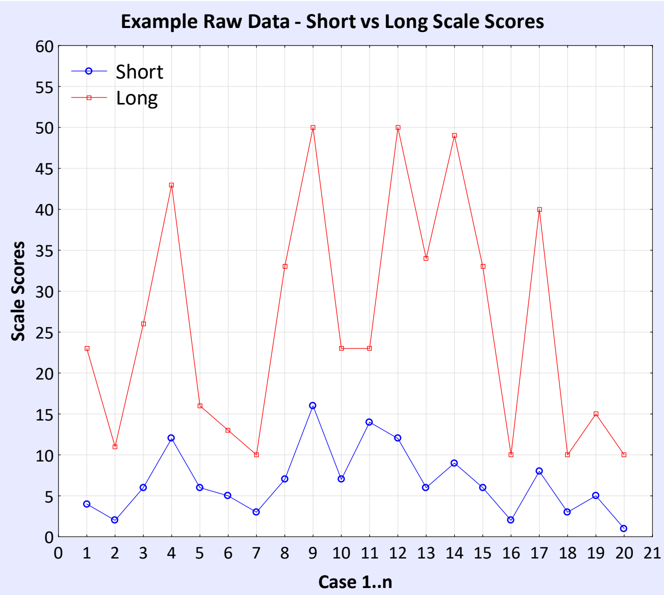


Figure 12: Example raw data line plot

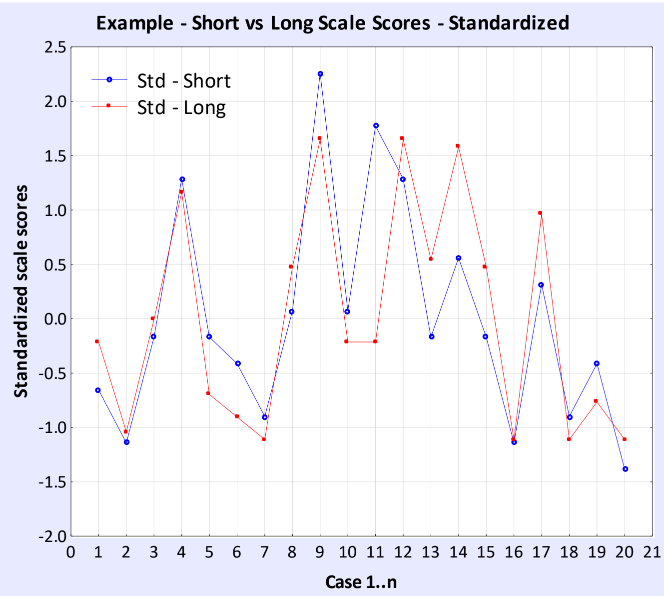


Figure 13: Example standardized data line plot

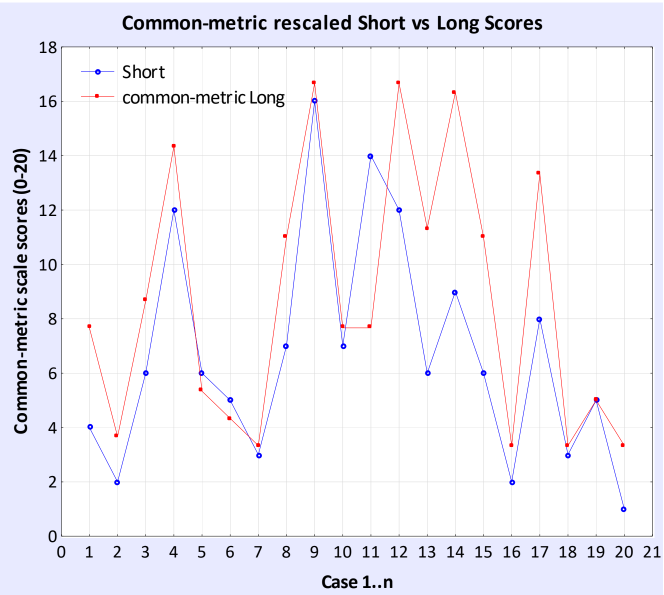


Figure 14: Example common-metric rescaled data line plot

The rescaling is achieved by linearly regressing the original magnitude range for a variable onto the new range, using the original magnitude minimum and maximum for a variable, and the chosen metric minimum and maximum values (in essence, fitting a straight line between two points in 2-dimensional space). The result is that the conversion is linear over the range for all values.

The standard linear regression equation is:

$$b = \frac{\left(\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i\right)}{\left(n\sum_{i=1}^{n} x_i^2 - \left(\sum_{i=1}^{n} x_i\right)^2\right)} \qquad a = \frac{\left(\sum_{i=1}^{n} y_i - b\sum_{i=1}^{n} x_i\right)}{n}$$

where

$n = 2\ (always)$

$x_1 =$ the original (*to be scaled*) variable minimum

$x_2 =$ the original (*to be scaled*) variable maximum

$y_1 =$ the minimum value within the new metric

$y_2 =$ the maximum value within the new metric

Which for just two values for each variable (the minima and maxima for each), simplifies to:

$$x_{new\_rescaled\_value} = \left[\left(\frac{x_{orig} - x_{\min}}{x_{\max} - x_{\min}}\right) * \left(y_{\max} - y_{\min}\right)\right] + y_{\min}$$

where

$x_{orig} =$ the original (*to be rescaled*) observation

$x_{\min} =$ the minimum possible value of x_{orig}

$x_{\max} =$ the maximum possible value of x_{orig}

$y_{\min} =$ the minimum possible value in the new metric

$y_{\max} =$ the maximum possible value in the new metric

So, for case 1 in our example data Table, we have:

$x_{orig} =$ the original (*to be rescaled*) observation $= 23$

$x_{\min} =$ the minimum possible value of $x_{orig} = 0$

$x_{\max} =$ the maximum possible value of $x_{orig} = 60$

$y_{\min} =$ the minimum possible value in the new metric $= 0$

$y_{\max} =$ the maximum possible value in the new metric $= 20$

$$x_{new\_rescaled\_value} = \left[\left(\frac{x_{orig} - x_{\min}}{x_{\max} - x_{\min}}\right) * \left(y_{\max} - y_{\min}\right)\right] + y_{\min}$$

$$x_{new\_rescaled\_value} = \left[\left(\frac{23 - 0}{60 - 0}\right) * (20 - 0)\right] + 0 = 7.6667$$