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The relationship between IQ and performance on the MATRICS consensus cognitive battery

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ABSTRACT

The associations between IQ and individual tests of neurocognitive function are well studied. However, there is a lack of information as to how IQ relates to performance on neuropsychological test batteries as a whole and in the same individuals. In this study, 250 healthy participants aged 20-69 years were tested with the Wechsler Abbreviated Scale of Intelligence (WASI) and the MATRICS Consensus Cognitive Battery (MCCB). In correlation analyses, IQ was significantly related to all MCCB scores, except the Social Cognition domain. Hierarchical regression analyses including gender, age, and education confirmed this association. For overall cognitive function, 50% of the variance was explained by IQ and demographic characteristics. For the domains Speed of Processing, Working Memory, Visual and Verbal Learning, IQ explained a larger proportion of the variance than the demographic factors did. The implication is that these domains may provide information of a person's intelligence level.

1. Introduction

Impaired neurocognitive function is one of the core features of schizophrenia spectrum disorders (Green et al., 2004). Assessment and treatment of cognitive deficits in schizophrenia requires the employment of comprehensive, standardized test batteries describing cognitive function across several domains. One such battery is the Measurement and Treatment Research to Improve Cognition in Schizophrenia [MATRICS] Consensus Cognitive Battery (MCCB), using ten tests to assess seven neurocognitive domains (Nuechterlein & Green, 2006). It is often referred to as the gold standard for neuropsychological assessment in schizophrenia, but has also been employed in other conditions of psychopathology, e.g., bipolar disorder (Burdick et al., 2011).

In addition to the United States norms for the healthy 20-59 age group (Nuechterlein & Green, 2006), Spanish (Rodriguez-Jimenez et al., 2012), Norwegian (Mohn et al., 2012), Japanese (Kaneda et al., 2013) and Singaporean (Rapisarda et al., 2013) reference data have been published for the MCCB.

General intellectual function and neuropsychological test performance are related, but are separate constructs, as the degree of neuropsychological test variance explained by IQ is significant, but not complete (Ackerman et al., 2005; Ardila, 1999; Diaz-Asper et al., 2004). The associations of IQ scores to the scores of most of the MCCB subtests have been reported. However, it is important to establish how IQ is related to performance on the MCCB as a whole, in the same individuals, and in large samples across relevant demographic variables. Moreover, many clinical neuropscyhologists routinely add IQ tests to their assessment of general cognitive function. However, a prolonged and fatiguing test session should be avoided if necessary, and IQ testing on top of a comprehensive neurocognitive function assessment could be redundant if the relationship between IQ scores and other measures of cognitive function is strong.

The relationship between IQ and the MCCB test scores as a whole has recently been investigated (August et al., 2012). In 77 healthy individuals between the ages of 18 and 55, the statistically significant correlations between the full IQ score and the cognitive domains of the MCCB ranged between .43 (Attention/Vigilance) and .70 (the Composite score). Corresponding associations were found in the group of individuals with schizophrenia. Limitations of this study were the relatively low number of participants and the restricted age range.

We have previously described gender, age, and education level differences in MCCB performance in healthy Norwegians (Mohn et al., 2012). In the current study, we use a large, expanded age range sample to describe the contribution of IQ to the variation explained by the demographic factors. The overall aim is to put previous reports (August et al., 2012) of a significant IQ-MCCB relationship on a more secure footing.

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2. Methods

2.1. Participants

The 250 participants represented five age groups: 20–29, 30–39, 40–49, 50–59, and 60–69 years, with 50 individuals (25 men and 25 women) in each group. The participants were recruited through advertisements in the local newspapers in Oslo and the south-eastern region of Norway and though electronic advertisements on the Vestre Viken Hospital Trust (VVHF) homepage.

Exclusion criteria (self-reported) were a history of schizophrenia or other severe mental disorder; mental retardation; a history of neurological disease; head injury and/or loss of consciousness for more than 10 minutes; current psychotropic medication; chronic somatic illness inducing significant fatigue or pain; current narcotics for pain; a history of alcohol or substance abuse; dyslexia or other significant learning difficulties; and inability to understand spoken and written Norwegian sufficiently to comprehend testing instructions.

The level of education distribution reported by Statistics Norway in 2005 (for the 20–59 years age group) and 2011 (for the 60–69 years age group) served as guidelines during the recruitment procedure, so that the education levels (elementary school, high school, or college) within each of our age cohorts were similar to those reported for the general population. For the entire sample (N = 250), mean age was 44.3 years (SD 14.0) and mean years of education was 12.8 (SD 2.6).

The participants were tested at the University of Oslo or at the hospitals at Bærum, Blakstad, Drammen, or Kongsberg. Each participant received a fee of NOK 400 (approximately US$65) for their participation. Before the testing session, each participant filled in an informed consent form. This study was approved by the Regional Committee for Research Ethics for Health Region South-East (REK Sør-Øst).

2.2. Neuropsychological assessments

The ten tests of the MCCB are the following: Trail Making Test A (TMT-A; US War Department, 1944), Symbol Coding (Brief Assessment of Cognition in Schizophrenia, BACS; Keefe, 1999), The revised Hopkins Verbal Learning Test (HVLT-R, immediate recall; Brandt & Benedict, 2001), Spatial Span (The Wechsler Memory Scale, SS-WMS; Wechsler, 1997), The University of Maryland Letter Number Span test (LNS; Gold et al., 1997), The revised Brief Visuospatial Memory Test (BVMT-R; Benedict, 1997), The Mazes test (Neuropsychological Assessment Battery, NAB; White & Stern, 2003), Category Fluency (Fluency; Blair & Spreen, 1989), The Managing Emotions part of the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT; Mayer et al., 2002), and The Continuous Performance Test – Identical Pairs (CPT-IP; Cornblatt et al., 1988).They were translated from English to Norwegian and then back to English by two bilingual experienced research psychologists, i.e., through an academic translation procedure (Nuechterlein & Green, 2009). The translated version of the MCCB was approved by the US test and battery intellectual property owners.

These ten tasks were reduced to seven cognitive domains: Speed of Processing (TMT-A, BACS, and Category Fluency), Attention/Vigilance, Working Memory (WMS-SS and LNS), Verbal Learning, Visual Learning, Reasoning/Problem Solving, and Social Cognition. An additional overall Composite score is calculated from these seven domains. As there are no internationally published MCCB norms for individuals older than 59 years, the current data analyses are made with our own calculated T scores ($M = 50, SD = 10$). These T scores are not adjusted for gender, age, or education level. Therefore, these demographic variables will be included in the regression analyses described below. Raw scores and Norwegian T scores of the 20-59 years group have been presented elsewhere (Mohn et al., 2012).

General intellectual function was assessed by the Norwegian version of the full Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 2007). The WASI provides an estimated of the general IQ score based on four subscales (Vocabulary, Similarities, Block Design, and Matrices). The Vocabulary and Similarities scales may be combined into a Verbal IQ score, and the Block Design and Matrices into a Performance IQ score. The WASI full IQ score has been reported to be nearly identical to the full IQ score as assessed by the comprehensive Wechsler Adult Intelligence Scale (WAIS) in a Norwegian sample (*r*. 93) (Bosnes, 2009). The correlations between the two assessments of Verbal IQ and Performance IQ were *r* .88 and *r* .86, respectively (Bosnes, 2009).

The assessment procedure, lasting up to 1.5–2 h, was carried out by a clinical psychologist trained in neuropsychological testing. The participants were informed that they could take short breaks between tests if needed.

2.3. Statistics

All statistical procedures were carried out using IBM SPSS Statistics version 20. Analyses of skewness and kurtosis showed that all data were normally distributed, the exception being the Visual Learning score, which had a slight kurtosis of 1.01 (*SE* 0.31).

Differences in IQ were studied with independent samples *t*-tests with gender as a grouping variable and ANOVAs with age and education level categories as grouping variables (Table 1).

In order to identify significant associations between IQ and the MCCB domains, first a series of Pearson's correlation analyses were run (Table 2). Then, linear hierarchical regression analyses were performed: The dependent variable was an MCCB domain. In step 1, gender, age, and years of education (age and years of education were entered as continuous variables) were entered as independent variables. In step 2, IQ was added as an independent variable (Table 3). The step 2 analyses were then repeated with either Verbal IQ or Performance IQ as independent variables.

3. Results

3.1. Differences in IQ scores

There were statistically significant increases in IQ with increasing levels of education, but no effect of gender or age (Table 1).

Table 1
IQ scores of the participants (N = 250).

	Full IQ
Entire sample	109.7 (11.7)
Gender differences	
Men (n = 125)	109.1 (11.7)
Women (n = 125)	110.3 (11.7)
	$t_{(df\ 1,249)} = 0.83$
Age differences	
20–29 years (n = 50)	109.6 (12.3)
30–39 years (n = 50)	108.3 (11.3)
40–49 years (n = 50)	107.8 (12.2)
50–59 years (n = 50)	110.7 (10.5)
60–69 years (n = 50)	112.0 (12.0)
	$F_{(df\ 4,245)} = 1.08$
Education differences	
Elementary school (n = 42)	104.9 (12.0)
Senior high school (n = 142)[#]	108.3 (11.8)
BA degree or higher (n = 79)	114.5 (9.7)
	$F_{(df\ 2,347)} = 12.03^{*}$

IQ in mean (SD). *t*: significance test of the gender differences. *F*: significance test of the age and education level differences.
* $p < .001$, Bonferroni corrected.
[#] Senior high school is not compulsory in Norway.

Table 2
Correlations between cognitive domains, demographic variables and IQ (N = 250).

Cognitive domains	Gender	Age	Education	Full IQ
Composite score	−.10	−.06	.24*	.60*
Speed of Processing	−.09	.01	.10	.39*
Attention/Vigilance	.04	−.08	.17*	.26*
Working Memory	−.24*	−.08	.25*	.51*
Verbal Learning	−.10	−.08	.26*	.43*
Visual Learning	.01	.20*	.19*	.54*
Reasoning/Problem Solving	.11	.04	.13	.37*
Social Cognition	−.17*	−.25*	−.01	.09

Pearson's correlations, 2-tailed.
* $p < .01$, Bonferroni corrected.

3.2. The relationship between IQ and MCCB performance

There were several statistically significant correlations between demographic variables (gender, age, and education) and the MCCB domains (Table 2). Moreover, all of the correlations between IQ and cognitive domains were significant, the exception being Social Cognition, whose relation to IQ did not reach statistical significance (Table 2).

When gender, age, and education were entered into the regression analyses with the MCCB domains as dependent variables (Step 1), there were several significant associations between age and cognitive performance, and a smaller number of significant relations between gender and education and test scores (Table 3). Adding IQ to the independent variables (Step 2) revealed positive, significant associations between IQ and MCCB domains, with a corresponding increase in explained variance from Step 1 (Table 3). The highest level of explained variance was found for the Composite score in Step 2 (50%). Again, there were no significant relationship between IQ and Social Cognition.

These results were only marginally altered when Verbal IQ or Performance IQ instead of the full IQ score was entered into the analyses at step 2 (data not shown). With Verbal IQ as independent variable, the level of explained variance ranged from 37% (the Composite score) to 7% (Social Cognition). With Performance IQ as independent variable, the level of explained variance ranged from 49% (the Composite score) to 6% (Social Cognition).

Table 3
Hierarchical regression models of the relationship between neurocognitive domains, demographic variables, and IQ (N = 250).

	Step 1			Step 2	
	$F_{(df\ 3,241)}$		Adj. R^2	$F_{(df\ 4,240)}$	Adj. R^2
	Gender (β)	Age (β)	Educ. (β)	IQ (β)	
Composite score	23.02***	.21		61.72***	.50
	.01	−.41***	.21***	.56***	
Speed of Processing	13.54***	.13		25.77***	.29
	−.11	−.34***	.10	.42***	
Attention/Vigilance	9.32***	.09		10.98***	.14
	.19*	−.21**	.18*	.24***	
Working Memory	17.15***	.17		37.59***	.38
	.05	−.36***	.19*	.48***	
Verbal Learning	9.92***	.10		21.99***	.26
	−.13	−.15	.23***	.42***	
Visual Learning	12.37***	.12		37.28***	.37
	.05	−.31***	.17*	.53***	
Reasoning/Probl. Solving	22.87***	.21		28.58***	.31
	.23***	−.39***	.15	.34***	
Social Cognition	6.68***	.07		5.86***	.07
	−.26***	−.12	−.05	.12	

Step 2: *F* and adjusted R^2 represent the full model with gender, age, education, and IQ as independent variables.
* $p < .05$, Bonferroni corrected.
** $p < .01$, Bonferroni corrected.
*** $p < .001$, Bonferroni corrected.

4. Discussion

4.1. General associations between IQ and MCCB performance

This study aimed at examining the relationship between IQ and the MCCB subtests in a group of healthy individuals between the ages of 20 and 69. There were small to moderate positive correlations between IQ and all but one domain of the MCCB. The strongest correlation was that of r .60 between full IQ and overall cognitive function (the Composite score). In general, these results were comparable to those reported by August et al. (2012) in a much smaller sample. However, the correlations of August et al. (2012) were larger than ours. Possibly, this is due to several demographic differences: Compared to the August et al. sample, the mean age of our sample was three years higher, the mean level of education was two years lower, our sample was ethnically homogenous, and with an equal proportion of men and women.

Adding IQ to the independent variables gender, age, and education into hierarchical regression analyses (Step 2) generally increased the level of explained variance, the highest being for the Composite score (50%) and Working Memory (38%), and the lowest for Attention/Vigilance (14%). For four cognitive domains (Working Memory, Visual Learning, Speed of Processing, and Verbal Learning), IQ accounted for the majority of the variance. However, similar to other reports (Testa et al., 2009), much of the variance was still explained by demographic factors, as expected due to our use of unadjusted T scores.

4.2. Associations between IQ and MCCB domains

We found a significant impact of IQ on Speed of Processing, in line with the general literature (Luciano et al., 2001; Vernon, 1983). However, compared to the IQ-Speed of Processing relationship, there was a slightly stronger association between IQ and Working Memory. Similar results have been reported by others (Fry & Hale, 2000). Working Memory is a more complex function than Speed of Processing, and may therefore be more strongly related to IQ (Ackerman et al., 2005; Luciano et al., 2001).

The change in level of explained variance from Step 1 to Step 2 was higher for Visual Learning (from 12% to 37%) than for Verbal Learning (from 10% o 26%), although both dimensions assess immediate recall across three learning sessions. A similar difference in the IQ-BVMT and IQ-HVLT relationship was reported by Testa et al. (2009). Possibly, the BVMT-R is harder to perform than the HVLT-R, as it requires drawing and not only verbal recall, providing an advantage for those with higher IQ.

The MCCB was not designed to assess executive functions (EF) directly, although the Mazes test underlying the Reasoning/Problem Solving domain may tap some of these functions. The term EF describe the ability to plan purposeful behavior, initiate responses, inhibit faulty responses, detect rules, concentrate despite environmental distractions, and relate to information in a rational and analytical manner. Hence, the EF are strongly associated with common definitions of intelligence (Sternberg, 1988; Thurstone, 1924; Wechsler, 1944). Not surprisingly, our regression model adding IQ to the demographic variables explained 31% of the variance of the Reasoning/Problem Solving domain. These results are in line with reports of performance on EF tasks and IQ tests being significantly related (Friedman et al., 2005; Salthouse et al., 2003).

IQ did not relate significantly to the Social Cognition domain. This result contributes to the debate as to whether Emotional Intelligence (EI), as assessed by the MSCEIT test also employed by the MCCB in assessing Social Cognition, is a separate entity from general intelligence (Roberts et al., 2001). Our results support the hypothesis that EI is not a part of general intelligence. Others have reported similar findings (August et al., 2012; Farrelly & Austin, 2007). In studies using other measures of EI than the MSCEIT, however, significant positive correlations between IQ and EI have been demonstrated (Roberts et al., 2001; Schulte et al., 2004). As the MSCEIT is assumed to possess better psychometric properties than the other scales of EI (Roberts et al., 2001), we are able to place confidence in our results.

4.3. Practical implications

Full IQ, Verbal IQ, and Performance IQ were all significantly related to MCCB performance in this study, and the strength of these associations was largely similar. Others (Baker et al., 1991) have reported similar findings in a study of Speed of Processing alone as the outcome variable. Hence, the researcher or clinician wishing to assess both IQ and MCCB performance, but is pressed for time or does not want to place excessive strain on the client, may obtain necessary information on this relationship without using the entire WASI battery.

In the face of significant co-variation between IQ and the MCCB scores, it may be argued that intelligence testing on top of the general neurocognitive assessment is redundant. We suggest that the researcher or clinician make this decision based on the parts of the MCCB in question. Ideally, the whole battery should be administrated together with an IQ test in order to obtain the most comprehensive picture of cognitive function. However, some participants are not able to sit through the entire test session. In those instances, the IQ assessment could be dropped and the subtests comprising the domains Speed of Processing, Working Memory, and Verbal and Visual Learning could be administrated to gain an approximate estimation of the individual's general intellectual function.

4.4. Strengths and limitations

The strengths of the present study are our relatively high number of participants, permitting the use of multivariate regression analyses, and our conservative statistics. These factors allow us a high degree of confidence in our results.

One possible limitation was a small significant positive correlation between IQ and years of education (r .31, $p < .001$), and this could theoretically create a co-linearity problem in the regression models. However, in Step 2 of the analyses, all tolerance coefficients were higher than .85, indicating that co-linearity did not affect our results.

Second, our sample was ethnically and geographically homogenous. All but three of our participants were Caucasian, and all of them were recruited from the south-eastern region of Norway. Therefore, our results do not necessarily generalize to other ethnic groups or geographical locations. Still, our sample was drawn from both urban and rural communities, rendering possible bias due to geographical restrictedness less likely.

Third, the Norwegian system of compulsory education has undergone important changes over the years. In 1969, the years of compulsory elementary schooling were changed from 7 to 9, and in 1997 from 9 to 10. Hence, the level of elementary education may not be directly comparable across the different age groups of our sample. Moreover, the level of compulsory elementary schooling is 12 years in the United States. This has implications for cross-cultural comparisons of IQ and neurocognitive function with education level as covariate.

A fourth limitation is the relatively high mean IQ score of the participants. Ideally, the association between IQ and other neurocognitive functions should be compared across groups with lower than average, average, and higher than average IQ scores. Such a procedure requires a larger number of participants than in our study.

Fifth, the strength of the relationship between IQ and neurocognitive function may be influenced by the type of tests in question. The MCCB consists of tests that are selected in order to be performed by individuals whose motivation is compromised by severe mental illness. Therefore, a ceiling effect may be at work in that the tests may be performed successfully also by individuals in the low IQ spectrum. Possibly, there is a stronger relationship to IQ in neuropsychological tests that are harder to perform.

Finally, compared to other batteries assessing IQ, the WASI may overestimate IQ levels (Axelrod, 2002). However, the IQ scores obtained by the Norwegian version of the WASI nearly overlap with those obtained by the Norwegian version of WAIS, with correlations ranging from .86 to .93 (Bosnes, 2009). Therefore, our results probably reflect a valid relationship between IQ and the MCCB in Norway, but may not necessarily generalize to populations using other translations of the WASI.

5. Conclusion

There was a significant relationship between IQ and MCCB performance, but this association was not overlapping, and demographic characteristics also contributed significantly to the test scores. The relationship to IQ was particularly strong for Working Memory, Speed of Processing, and Visual and Verbal Learning. The implication is that the score of these four domains could provide information of a person's intelligence level.

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Contributors

Christine Mohn Ph.D. performed the neuropsychological testing of the participants, performed the statistical analyses and drafted the manuscript. Kjetil Sundet Ph.D. initiated the Norwegian standardization of the MCCB project and provided statistical advice. Bjørn Rishovd Rund Ph.D. initiated the Norwegian standardization of the MCCB project and provided theoretical advice. All authors contributed to manuscript writing.

Conflict of interest

All authors declare that they have no conflicts of interest.

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