A New Zealand regression formula for premorbid estimation using the National Adult Reading Test.

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This study developed a regression formula for prediction of pre-morbid abilities using the National Adult Reading Test (NART), standardised for use in New Zealand, and including examination of the contribution of variables such as age, gender and ethnicity to prediction. Participants were 113 New Zealand born adults (age range 18 to 84; mean= 35.38; SD= 13.59), of whom 56 (49.6%) were male. Pakeha/Europeans comprised 80.5% (n= 91) of the sample while 18.6% (n= 21) were Māori, and one participant identified as of Pacific Island ethnicity. Participants completed the NART and subtests of the WAIS-III required to calculate Full Scale, Verbal and Performance Intelligence scores (FSIQ, VIQ, PIQ). Consistent with the literature Māori participants produced significantly lower scores than Pakeha on the indexes of the WAIS-III, whereas this was not the case for the NART. Increased age was also significantly related to lower WAIS-III performance but was not significantly related to the NART. Both NART and WAIS performance were significantly affected by years of education. Regression formulae were then developed to predict WAIS-III intelligence scores from NART error score, ethnicity, age, gender, and years of education. The original NART formula explained 42% of the variance in FSIQ in this sample, whereas the New Zealand formula developed here explained 82.1% of the variance in FSIQ. The New Zealand formulae also explained 71.9% of variance in VIQ and 40.5% of the variance in PIQ. These formulae predicted ability level well within the superior/very superior ranges of performance and tended to overestimate ability for those in the average and high average ranges of ability.

Neuropsychological assessments are typically used to assess level of functioning, and degree of cognitive decline. Ideally, previous measures of cognitive functioning would be used as a comparison; however, these are rarely available (Petito, 1999). Thus, a number of methods to estimate premorbid ability have been developed to provide a baseline against which current function is compared (Basso, Bornstein, Roper & McCoy, 2000; Franzen, Burgess & Smith-Seemiller, 1997). Ideally, such estimates must be both resilient to injury/disease, and correlate with overall level of ability, which is typically assessed as overall intelligence (IQ) (Spreen & Straus, 1998). The focus of this study was on use of tests of over-learned skills such as the NART to predict premorbid function, particularly when used in demographic regression formulae.

Tests of Over-learned Skills

Tests of over-learned skills (e.g., reading) are strongly associated with IQ, and relatively resilient to impairment (Franzen et al., 1997). One such test, the National Adult Reading Test (NART; Nelson & Willison, 1991), presents participants with a list of 50 irregularly spelled words of increasing difficulty that cannot be pronounced phonetically (e.g., 'debt'). It is assumed that these words must have been previously learnt in order for an individual to pronounce them correctly (Crawford, Dreary, Starr, & Whalley, 2001a).

When compared to other methods findings lend strong support for the NART in estimating premorbid ability. For example, the NART provides significantly better prediction of IQ than regression formulae based on demographic variables known to correlate with IQ (Bright, Jadlow & Kopelman; 2002; Griffin, Mindt, Rankin, Ritchie, & Scott, 2002; Jackson, 1993; McCarthy, Burns & Sellers, 2005), and NART performance is resilient to the effects of both brain injury and degenerative diseases (Bright et al., 2002; Cockburn, Keene, Hope & Smith, 2000; Law & O'Carroll, 1998; McCarthy, Burns & Sellers, 2005; McFarlane, Welch & Rodgers, 2006; Morrison, Sharkey, Allardyce, Kelly & McCreadie, 2000; Paolo et al., 1997; Rolstad, Nordlund, Gustavsson, Eckerton, Klang, Hansen, & Wallin, 2008; Sharpe & O'Carroll, 1991; Watt & O'Carroll, 1999).

Despite these positive findings, attempts have been made to improve accuracy of NART estimates further through combining test scores with demographic information. Age, sex, ethnicity, and level of education are highly correlated with IQ scores, and thus are considered important in predicting premorbid IQ (Barona, Reynolds & Chastain, 1984; Spreen & Strauss, 1998). Schoenberg, Scott, Duff and Adams (2003) found that combining WAIS-R scores and demographic variables produced very accurate premorbid estimates. Other studies have reported similar findings (Krull, Scott & Shearer, 1995; Vanderploeg & Shinka, 1995; Vanderploeg, Shinka, & Axelrod, 1996). Evidence from research combining NART scores and demographic variables suggests that these produce more accurate premorbid estimates than demographic variables alone (Crawford, Cochrane, Besson, Parker & Stewart, 1990; Crawford, Nelson, Blackmore, Cochrane, & Allen, 1990; Watt & O'Carroll, 1999), and also produces significantly more accurate estimates than the NART alone (Freeman & Godfrey, 2000; Freeman, Godfrey, Harris & Partridge, 2001; Watt & O'Carroll, 1999).

While the predictive ability of the NART is improved when used in regression formulae alongside demographic variables known to impact IQ, as noted by Harnett, Godfrey and Knight (2004), whilst regression equations are useful when used with populations that they have been standardised on, they lack accuracy and may be invalid for other groups. There are currently no such regression equations available which have been developed and/or standardised for the New Zealand (NZ) population. This is of particular relevance given evidence that NZ test performance is impacted by cultural bias, as outlined below.

Cross Cultural Validity

Most neuropsychological tests, including those used for premorbid estimation, are standardised and have their norms based on English speakers American or British populations (Feigin & Barker-Collo, 2007) and may therefore be subject to cultural bias, which is the tendency for tests to reflect their culture of origin (Barker-Collo, 2007). That is, individuals from the same culture as a test's developers perform better on that test, while those from other cultures perform worse (Anastasi & Urbina, 1997). This has serious implications for premorbid estimation, and will therefore have repercussions for diagnosis, rehabilitation recommendations, and compensation (Ogden, Cooper & Dudley, 2003).

In NZ there is a growing body of evidence that New Zealanders in general, and Māori in particular produce significantly lower scores when compared to age-adjusted North American normative data. This is particularly true of verbal abilities tests such as WAIS-R vocabulary (Ogden & McFarlane-Nathan, 1997), and Boston Naming Test (Barker-Collo, 2001; Barker-Collo, 2007), and tests of verbal memory such as the California Verbal Learning Test-II (Barker-Collo, Clarkson, Cribb & Grogan, 2002). As a verbal test, these findings have implications for the use of the NART.

Recently, Barker-Collo, Bartle, Clarke, van Toledo, Vykopal and Willetts (2008) investigated the accuracy of premorbid estimates in NZ using the NART and Spot the Word among healthy adults. These authors report that although STW estimates were strongly correlated with WAIS-III scores for Europeans and Māori, the NART was not significantly correlated with the WAIS-III for Māori. Halliday (2006) also found that the NART is not a good predictor of performance for New Zealanders, and that in general, both Pakeha and Māori do better on a NZ version of the test. One means of increasing the accuracy of NART estimates for New Zealanders would be to develop a NART regression equation from a large sample of healthy NZ adults. Such a formula could include demographic factors, such as ethnicity, that are known to alter predictive accuracy of existing formulae that are solely based on NART test scores.

Purpose

The purpose of this study was to develop a NART regression formula for prediction of IQ, standardised for use in NZ. This included examination of the contribution of variables such as age, gender and ethnicity to prediction of IQ. Due to the timing of data collection the WAIS-III was administered to provide IQ scores for this study. With the introduction of the WAIS-IV in 2008, Verbal and Performance IQ scores will no longer be generated. However, as noted in the WAIS-IV administration and scoring manual (Wechsler, 2008) "The terms VCI (*Verbal comprehension index*) and PRI (*Perceptual Reasoning Index*) should be substituted for the terms VIQ and PIQ in clinical decision-making and other situations where VIQ and PIQ were previously used" (p. 5).

Method

Participants

Participants were 113 NZ born adults who ranged in age from 18 to 84 years (mean= 35.38; *SD*= 13.59). The sample had spent an average of 1.32 years outside NZ (*SD*= 3.31), and 56 (49.6%) were male. In regard to ethnicity, Pakeha/NZ European comprised 80.5% (*n*= 91) of the sample while 18.6% (*n*= 21) were Māori, and one participant identified as of Pacific Island ethnicity. Those with higher levels of education were over-represented with the average level of education in the sample being 14.73 years (*SD*=2.86) and ranged from 9 to 26 years. The majority of the sample were right handed (*n*= 69; 61.1%), with the remaining 40 (35.4%) being primarily left handed and 4 (3.5%) being ambidextrous. Participants came from a range of employment backgrounds including 32 secondary and tertiary students (28.3%), 19 labour and or clerical workers (16.8%), 31 skilled labourers (27.4%), and 31 professionals (27.4%). Most participants reported being single (*n*= 71; 62.8%), while 27 (23.9%) were married, 8 (7.1%) were in common-law/de facto relationships, and 7 (6.2%) were divorced/separated. Participation was limited to NZ born adults for whom English was a first language. Individuals with a history of head injury, learning disability, or current mental health issue were excluded.

Measures

All participants completed the NART and those subtests of the WAIS-III required to obtain Full Scale, Verbal and Performance IQ scores, as described below. These were administered and scored in accordance with standardised procedures.

National Adult Reading Test (NART; Nelson & McKenna, 1975). The NART is a test of 50 irregularly spelled words of increasing difficulty that cannot be pronounced phonetically, for example 'debt' and 'psalm'. During the test participants read all of the 50 words aloud, in order, and any errors made are recorded; with scoring out of a maximum of 50. Participants were encouraged to attempt every word. Administration took approximately 10 minutes. The logic underlying the

NART is that the words must have been previously learnt in order for an individual to pronounce them correctly (Crawford, Dreary, Starr, & Whalley, 2001a).

The NART has high split-half (r=0.93; Nelson & Willison, 1991), inter-rater (0.96 – 0.98; Schlosser & Ivison, 1989), and test-retest reliability (r=0.98; Crawford, Parker, Stewart, Besson, & DeLacey, 1989), as well as high internal consistency (α=.90; Crawford, Stewart, Garthwaite, Parker & Besson, 1988). The NART has also been found to have high validity as a measure of general intelligence as reviewed in detail in the literature review, with correlation of the NART with tests of intelligence of 0.85 (Crawford et al, 1989). The NART predicted FSIQ, VIQ, and PIQ scores were calculated from the NART total score using the existing NART formula from the technical manual (Nelson & Willison, 1991).

Wechsler Adult Intelligence Scale-III.(WAIS-III; Wechsler, 1997). The WAIS-III measures IQ through a combination of verbal and nonverbal subtests for individuals aged 16 to 89 years. Only those subtests required to calculate VIQ, PIQ and FSIQ were administered. All subtests were administered using standard procedures as per the test manual and have a scaled score mean of 10 and standard deviation of three. Briefly, the verbal subtests were: 1) Vocabulary (33 items) – items involve defining orally presented words, 2) Similarities (19 items) – where the relationship between two items or concepts is described, 3) Arithmetic (20 items) – solve simple mental arithmetic problems, 4) Digit Span (30 items) – repeat a set of digits of varying length presented orally, 5) Information (28 items) – questions about general factual information, 6) Comprehension (18 items) – questions about social knowledge and practical information. Performance subtests administered were: 1) Picture Completion (25 items) – tests ability to see details and visual recognition, 2) Digit Symbol Coding (133 items) – visuomotor speed and scanning accuracy are tested by transcribing symbols in boxes, 3) Block Design (14 items) – participants must create geometrical patterns with blocks, 4) Matrix Reasoning (26 items) – identifying the correct piece of an incomplete pattern in order to complete it 5) Picture Arrangement (11 items) – arranging a set a visual images in a sequence that makes a coherent story.

Administration of all subtests took approximately two hours. Each subtest was scored and these raw scores were converted into standard scores using age-adjusted normative data. FSIQ, VIQ and PIQ scores were derived through summing relevant scales scores and converting these using tables provided in the manual, in accordance with standardised procedures. All IQ scores have a mean of 100 and standard deviation of 15. The WAIS-III was standardised on a sample of 2540 individuals between the ages of 16 and 89 years old. It has a high reliability coefficient of 0.98 (Lezak, Howieson, & Loring., 2004) and also high validity, with correlations between WAIS-III FSIQ and other measures of IQ (e.g., WAIS-R, WISC-III, Stanford-Binet-IV) ranging from .88 (Thorndike, Hagen & Sattler, 1986) to .93 (Wechsler, 1997).

Procedure

Ethical approval was obtained for this project from the University of Auckland Human Subjects Ethics Committee. Participants were obtained

Table 1: Means and standard deviations of performance across the NART and WAIS-III.

Measures	Total Sample (n = 113)	
	Mean	SD
NART		
Total Score	31.49	6.82
NART FSIQ	112.41	5.64
NART VIQ	111.56	4.40
NART PIQ	111.99	6.27
WAIS- III Subtest Scaled scores		
Picture Completion	11.50	2.69
Vocabulary	13.43	2.85
Digit Symbol Coding	10.11	3.72
Similarities	11.90	2.81
Block Design	12.95	3.08
Arithmetic	10.81	2.82
Matrix reasoning	13.25	2.27
Digit Span	10.94	2.95
Information	11.77	3.04
Picture Arrangement	11.14	3.36
Comprehension	13.03	2.96
WAIS-III IQ scores		
FSIQ	113.55	14.91
VIQ	112.38	15.15
PIQ	112.92	15.09

Note: SD = Standard deviation, WAIS-III = Wechsler Adult Intelligence Scale III, NART = National Adult Reading Test, FSIQ= Full Scale IQ, VIQ= Verbal IQ, PIQ = Performance IQ. All WAIS-III subtests have a mean of 10 and SD of 3; IQ scores have a mean of 100 and SD of 15.

through word of mouth, posting of study information on notice boards on the University of Auckland campuses, and presentations and/or provision of Participant Information Sheets to community organisations (i.e., Age Concern, Grey Power, and Community Churches). All potential participants were provided with Participant Information Sheets and Consent Forms. Consent forms included a section for participant contact details. Where these were completed and returned to the researcher, the researcher then contacted the participant to schedule an assessment session.

The average length of each testing session was 2.5 hours and the testing took place in either participant's homes or in rooms provided by the University, or other suitable venue at participants' convenience. When tests were conducted in participants homes every effort was made to ensure the testing environment was appropriate so as to minimise distractions that may impact test performance, such as turning off cell phones and TV's and, asking others to leave the room.

At the start of each session the Participant Information Sheet was reviewed, including the voluntary nature of participation and option to withdraw at any time, and the participant was given the opportunity to ask questions about the research and testing procedure. If they had not already done so participants were asked to read and sign the consent form. They were then asked to complete a demographics form which asked for relevant information about ethnicity, age, gender, handedness, and history of head injury and mental illness. Order of administration of WAIS-II and NART were counterbalanced. Breaks were provided as necessary. Once all data were collected each test was scored and then results were entered into an SPSS 17.0 file for analysis.

Results

The results of this study are presented in four sections. First, the means and standard deviations obtained by the participants across the measures are presented. Group differences in performance using groups based on gender and ethnicity, as well the relationships between performance and continuous demographic variables (i.e., age, years of education) are then examined. This is followed by an examination of the relationships between NART and WAIS-III IQ scores and regression analysis to develop a NZ formula for predicting WAIS-III IQ scores from the NART. The predictive accuracy of the existing NART formula and the NZ-NART formula developed here are then contrasted.

Overall Performance

Table 1 presents the means and standard deviations obtained by the sample across measures. As seen in Table 1, average performance of the sample on the NART equated to high average estimates of FSIQ, VIQ and PIQ. In terms of the WAIS-III subtests, participants performed in the high average range for Vocabulary, Similarities, Block Design, Matrix Reasoning, Information, and Comprehension subtests. Performance fell within the average range for Digit Symbol Coding, Digit Span, Arithmetic, and Picture Arrangement. Performance was on the cusp of the average and high average ranges for Picture Completion. Average obtained WAIS-III FSIQ, VIQ and PIQ were similar to those obtained on the NART, falling within the high average range.

The difference between WAIS-III obtained and NART calculated FSIQ, VIQ, and then PIQ were examined through a series of repeated measures within-subjects contrasts. The findings indicate no significant difference between obtained and predicted FSIQ scores ($F(1, 112) = 1.016$ $p = .316$), VIQ scores ($F(1, 112) = 0.125$, $p = .725$), or PIQ scores ($F(1, 112) = 1.140$, $p = .288$). In terms of the strength of relationship of FSIQ, VIQ, and PIQ scores derived from the two tests, the correlations were significant ($r_{FSIQ} = .650$, $p < .001$; $r_{VIQ} = .674$, $p < .001$; $r_{PIQ} = .477$, $p < .001$), indicating a moderate level of agreement between the calculated NART IQ score and the obtained WAIS-III IQ scores.

Impact of Demographics

The impact of demographic variables on WAIS-III and NART IQ scores were then examined using a 2 x 2 MANOVA with groups based on gender and ethnicity (Pakeha, other) was conducted, with NART and WAIS-III FSIQ, PIQ and VIQ scores as dependent variables. The results show that using Wilks' criteria there were significant main effects of gender ($F(4, 106) = 5.364$, $p = .001$, $\eta^2 = .17$), and ethnicity ($F(4, 106) = 7.634$, $p < .001$, $\eta^2 = .22$). The interaction between the two was not significant. Contributing significantly to the main effect of gender were VIQ ($p = .029$) and FSIQ ($p = .047$); with males producing higher means ($Mean_{VIQ}$=116.07; $Mean_{FSIQ}$=117.04) than females ($Mean_{VIQ}$=108.75; $Mean_{FSIQ}$=110.12). Contributing significantly to the main effect of ethnicity were WAIS-III VIQ ($p < .001$), PIQ ($p < .001$) and FSIQ ($p < .001$);

Table 2: Bi-variate Correlations between NART and WAIS-III IQ scores and Years of Education.

Measure	Years of Education	Age in Year
NART		
FSIQ	.469***	ns
VIQ	.469***	ns
PIQ	.469***	ns
WAIS-III		
FSIQ	.530***	-.211**
VIQ	.544***	-.320**
PIQ	.394***	ns

*** $p < .001$
** $p < .01$
ns = not significant ($p > .05$)
Note: WAIS-III = Wechsler Adult Intelligence Scale III, NART = National Adult Reading Test, FSIQ= Full Scale IQ, VIQ= Verbal IQ, PIQ = Performance IQ.

with Pakeha producing significantly higher mean scores ($Mean_{VIQ}$=115.01; $Mean_{PIQ}$ = 116.12; $Mean_{FSIQ}$= 116.59) than others ($Mean_{VIQ}$=101.5; $Mean_{PIQ}$ = 99.68; $Mean_{FSIQ}$= 100.95). None of the other variables contributed significantly to prediction ($p > .05$).

To examine the relationships between performance on the NART and WAIS-III, and continuous demographic variables (i.e., age, years of education), bi-variate correlations were generated. As seen in Table 2, increased years of education was associated with better performance across IQ scores from both the NART and WAIS-III, while increased age in years was associated with lower WAIS-III VIQ and FSIQ scores.

Regression Analyses

In this stage of the analyses, regression formulae were generated to predict WAIS-III FSIQ, VIQ, and PIQ scores from the NART error score and demographics including ethnicity, gender, age, and years of education as potential moderators of performance. To determine if the addition of demographic factors to the NART score improved prediction of FSIQ, these were entered in two steps. In the first step, only the NART error score was entered into the equation, while in step two demographic variables were added. The NART alone predicted a significant amount of variance in FSIQ (R^2=.650; F(1, 111) = 81.306, $p < .001$), accounting for 65% of the variance in FSIQ. With addition of demographic variables to the equation, prediction significantly improved (R^2_{change}=.252, F_{change}(4, 107) = 20.669, $p < .001$), accounting for 82.1% of the variance in WAIS-III FSIQ and with a standard error of the estimate of 7.21. Contributing significantly to prediction were the NART error score ($p < .001$), years of education ($p < .001$), ethnicity ($p < .001$), and gender ($p < .001$). The resulting formula for prediction of FSIQ was (where for ethnicity Pakeha = 1 and Other = 2; and for gender male = 1 and female = 2):

NZ - Predicted FSIQ = 145.716 + (-1.063x NART error score) + (1.31 x years of education) + (-11.98 x ethnicity) + (-8.2 x gender)

The correlation between the WAIS-III FSIQ and this new NZ- predicted FSIQ score was r = .811, $p < .001$; which is slightly greater than that reported above for WAIS-III FSIQ and the existing NART FSIQ formula (r= . 650, $p < .001$).

For WAIS-III VIQ, with only the NART entered into the equation, prediction was significant (R^2=.454; F(1,111) = 92.269, p<.001), accounting for 45.4% of the variance in VIQ. When demographic variables were added to the equation this significantly improved prediction (R^2_{change}=.265, F_{change}(4, 107 =25.272, p<.001), overall accounting for 71.9% of the variance in WAIS-III VIQ with a standard error of the estimate of 7.23. Contributing significantly to prediction were the NART error score ($p < .001$), age in years ($p < .001$), years of education ($p = .003$), ethnicity ($p < .001$), and gender ($p < .001$). The resulting formula for prediction of VIQ was (where for ethnicity Pakeha = 1 and Other = 2; and for gender male = 1 and female = 2):

NZ- Predicted VIQ = 152.471 + (-1.267 x NART total score) + (-0.390 x age in years) + (1.009 x years of education) + (-9.343 x ethnicity) + (-6.923 x gender).

The correlation between the WAIS-III VIQ and this new NZ- predicted VIQ score was r = .846, $p < .001$; which, as for FSIQ, is slightly greater than that reported above for WAIS-III VIQ and the existing NART VIQ formula (r= .674, $p < .001$).

For WAIS-III PIQ, with only the NART entered into the equation, prediction was significant (R^2=.228; F(1,111) = 32.694, p<.001), accounting for only 22.8% of the variance in PIQ. When demographic variables were added to the equation this significantly improved prediction (R^2_{change}=.178, F_{change}(4, 107 =7.993, p<.001), overall accounting for 40.5% of the variance in WAIS-III PIQ with a standard error of the estimate of 9.20. Contributing significantly to prediction were the NART error score (p =.004), years of education (p = .006), ethnicity ($p < .001$), and gender (p= .018). The resulting formula for prediction of PIQ was (where for ethnicity Pakeha = 1 and Other = 2; and for gender male = 1 and female = 2):

NZ-Predicted PIQ = 125.632 + (-.595 x NART total score) + (1.379 x years of education) + (-13.788 x ethnicity) + (-5.804 x gender).

The correlation between the WAIS-III VIQ and this new NZ- predicted PIQ score was r = .631, $p < .001$; which, as above, is slightly greater than that reported above for WAIS-III PIQ and the existing NART PIQ formula (r= .477, $p < .001$).

Predictive Accuracy of NZ-NART formulae

To investigate the predictive accuracy of the new NZ-NART formulae the frequency of accurate and inaccurate predictions of qualitative categories was examined. As premorbid estimation tends to focus on prediction of overall ability this analysis was limited FSIQ. The findings are presented in Table 3. Despite producing very different correlations to WAIS-III FSIQ, the two estimation formulae examined performed similarly overall, with the NZ-formula accurately predicting 43% of cases, compared to 38% for the existing NART formula. However, as seen in Table 3, the predictive accuracy of the NZ-NART formula developed here outperformed the existing NART formula for those whose WAIS-III scores fell within the superior and very superior ranges, while the existing NART formula performed best for those whose WAIS-III FSIQ scores were high average or average.

Discussion

This study aimed to develop a New Zealand regression formula for use in the prediction of premorbid ability, as previous studies had suggested that the current NART formula standardised on a British sample is not accurate for many New Zealanders (Barker-Collo et al., 2008). Overall, consistent with the literature Māori participants produce significantly lower scores than Pakeha on the indexes of the WAIS-III (Barnfield & Leathem, 1998; Ogden & McFarlane-Nathan, 1997); however NART scores did not reflect this, suggesting that the NART may be less inherently culturally biased for Māori. This finding replicates those of Barker-Collo et al, (2008) and Halliday (2006). Similarly, increased age was significantly related to lower WAIS-III performance but was not significantly related to the NART. Both NART and WAIS performance were significantly affected by years of education as expected by the literature (Lezak et al., 2004).

A regression formula to predict WAIS-III intelligence scores was developed which included NART error score, and demographic variables related to WAIS-III IQ scores (i.e., ethnicity, age, gender, and years of education). With these variables added, prediction of WAIS-III scores was significantly improved, with greater variance in scores accounted for than with the original NART formula.

The original, British population based NART formula was only able to explain 42% of the variance in FSIQ in this sample, leaving the majority of the variance unexplained. This is slightly less than in a previous NZ study (49%; Barker-Collo et al., 2008), and similar international studies where the NART was able to predict between 50% (Watt & O'Carroll, 1999) and 59% (Sharpe & O'Carroll, 1991) of variance. However, with the addition of demographic variables (ethnicity and years of education) the NZ-NART formula developed in this study was able to explain 82.1% of the variance in FSIQ, which is greater than that presented in international standards (e.g., Sharpe & O'Carroll, 1991), and vastly improves the accuracy of prediction. The New Zealand based formulae also explained 71.9% of variance in VIQ and 40.5% of the variance in PIQ, suggesting it is most accurate to use these formulae for predicting overall performance.

Such findings also support evidence in the literature that combining NART scores with demographic variables significantly improves the accuracy of prediction (e.g., Crawford, Cochrane, Besson, Parker & Stewart, 1990; Crawford, Nelson, Blackmore, Cochrane, & Allen, 1990; Freeman, et al, 2001). A Canadian study by Watt and O'Carroll (1999) found that combining the NART with demographic variables increased the variance in IQ explained from 50% to 60%, which is a similar level of improvement to the present study. Numerous other studies combining demographic variables with scores from other neuropsychological tests have produced comparable results (e.g., Krull, Scott & Shearer, 1995; Schoenberg, Scott, Duff & Adams, 2003; Vanderploeg & Shinka, 1995; Vanderploeg et al., 1996).

Despite this suggestion of increased predictive accuracy, it is important to look specifically at whether use of the new NZ-NART formula would actually improve predication of premorbid ability when if applied in clinical practice. The formula developed in this study tended to predict ability level well within the higher ranges of performance (i.e., superior, very superior), being most likely to overestimate ability for those in the average and high average ranges of ability. The existing NART formula outperformed the new NZ-NART formula for individuals performing in the average and above average ranges.

Clinical Implications

The NZ-NART formula accounted for 82.1% of the variance in FSIQ, and was able to accurately predict 65% of cases whose abilities fell within the superior and very superior ranges compared to only 5% accuracy in these same categories for the original British NART formula. While, as with any regression formulae further work is required to cross-validate these findings, this suggests that for those of high ability level, the new formula may provide clinicians with another method of premorbid estimation that is simple to score and quick to administer; and

Table 3: Accuracy of the NZ-NART and NART formulae for prediction of WAIS-III FSIQ categories.

	WAIS-III FSIQ			
	Very Superior (*N*=19)	Superior (*N*=18)	High Average (*N*=21)	Average (*N*=55)
NZ-NART FSIQ				
Very Superior	**15 (78.9%)**	7 (38.9%)	2 (9.5%)	--
Superior	4 (21.1%)	**9 (50.0%)**	6 (28.6%)	5 (9.1%)
High Average	--	2 (11.1%)	**9 (42.9%)**	33 (60.0%)
Average	--	--	4 (19.0%)	**16 (29.1%)**
Low Average	--	--	--	1 (1.8%)
NART FSIQ				
Very Superior	**0**	--	--	--
Superior	10 (52.6%)	**2 (11.1%)**	--	2 (3.6%)
High Average	9(47.4%)	16 (88.9%)	**15 (71.4%)**	26 (47.3%)
Average	--	--	6 (28.6%)	**26 (47.3%)**
Low Average	--	--	--	1 (1.8%)

Note: NZ-NART = New Zealand formula from the National Adult Reading Test, WAIS-III = Wechsler Adult Intelligence Scale III, FSIQ = Full Scale IQ. Text in bold represents proportion of estimates which fell within the same category for predicted and obtained FSIQ.

could also be used as a simple means of IQ estimation for research studies where this is a factor of interest. This is as compared to the average and high average ranges where the NZ-NART was accurate for 33% of cases while the existing formula was accurate in 54% of cases. Thus, we suggest use of the existing formula in these ranges.

Having noted this, it is important, as with any method of premorbid estimation, to supplement predictions with qualitative information such as achievement in hobbies, employment, and education, as no formula can fully account for the complexity of individual or cultural differences. Additionally, as noted by Harnett, Godfrey and Knight (2004) regression formulas are only useful when used with populations that they have been standardised on and lack accuracy and may be invalid when used with other groups. The NZ-NART formula developed here is based upon a sample of highly educated New Zealand born adults living predominantly in the Auckland region (with three from Hamilton or Whakatane) and, whilst appropriate and useful for these groups, it could not be used with confidence for other groups.

Strengths and Limitations

The greatest weakness of the present study is in its generalisability. While the formulas developed include age, education, ethnicity and gender as potential moderating factors, the sample on which these formulae are based was generally young, well educated, and predominantly European. Thus, additional studies with a larger and more diverse samples are required to determine if the formulae developed here require modification. This wider sampling should include those with a greater range of underlying abilities, education levels, ages, and other ethnic groups. It is also suggested that sampling allow examination of samples from less urban areas.

The study is strengthened by a number of factors including its relatively large sample of neurologically normal adults. Additionally, all participants completed the full WAIS-III, rather than the Wechsler Abbreviated Scale of Intelligence, thus providing a clearer and more accurate picture of the pattern of performance than that presented by other authors (e.g., Halliday, 2006). Although some authors might propose that the ideal is to create a New Zealand version of the NART, as has been done in the United States, such an attempt would be time consuming and costly given the need for large standardisation samples to establish norms. The present study allows for more accurate prediction of premorbid abilities using the NART via a simple formula that corrects for the influence of demographic characteristics, making the existing test more relevant for use in a New Zealand context.

Conclusion

While it was found that a New Zealand derived formula based on NART performance and demographics was able to predict a large proportion of variance in ability as measured by WAIS-III FSIQ, this translated to accurate prediction of ability level for those in the superior and very superior ranges. The existing NART formula was more accurate for those performing in the average and high average ranges. While further studies with a larger sample size, and participants from a greater range of ethnic groups, levels of education, localities, and ages would be recommended; this study represents a first step to providing New Zealand clinicians and researchers access to a brief estimation of intelligence which can be used with a known level of accuracy.

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