1994


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Estimation of premorbid intelligence: A combined demographic and psychometric approach

Friedberg, Sandra Cook, Ph.D.
The Louisiana State University and Agricultural and Mechanical Col., 1994
ESTIMATION OF PREMORBID INTELLIGENCE:
A COMBINED DEMOGRAPHIC AND PSYCHOMETRIC APPROACH

A Dissertation

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Louisiana State University and
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in

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by

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ABSTRACT

A combined demographic and present abilities approach to estimate premorbid intellectual functioning was developed and cross validated on unimpaired and closed head injured subjects. The non-clinical sample included 75 non-neurologically impaired individuals divided into two groups. The development sample (n=50) was used to generate linear regression equations to estimate WAIS-R IQs from the estimated Barona IQ score (Barona, Reynolds, & Chastain, 1984) plus error score on the National Adult Reading Test (NART; Nelson, 1982). The cross-validation sample (n=25) were individually matched to the clinical subjects on age, education, gender, and race variables. The clinical sample included 25 severe closed head injured (CHI) patients within one year post injury.

First, NART performance was shown to be a valid present abilities measure for the estimation of premorbid intelligence. NART performance was shown to be stable in patients with severe head injury. Correlations between obtained WAIS-R IQs and estimated NART IQs (Ryan & Paolo, 1992) were .84, .82, and .75 for FSIQ, VIQ, and PIQ, respectively. Mean NART error scores and estimated NART IQs were the same for CHI patients and matched controls, while mean obtained WAIS-R IQs were significantly lower for the CHI group. The discrepancy between obtained WAIS-R IQs and
estimated NART IQs was significantly larger for CHI subjects than for matched normal controls.

Next, regression equations to estimate WAIS-R IQs were developed by combining a stable measure of performance (NART error score) with the Barona et al. (1984) demographic estimation of WAIS-R IQs. The variance accounted for by the combined NART-Barona regression equations was 74.39% for FSIQ, 75.90% for VIQ, and 57.19% for PIQ. Standard errors of estimate were 8.56, 8.39, and 10.34 for FSIQ, VIQ, and PIQ, respectively. For the normal cross-validation sample, the correlations between obtained WAIS-R IQs and the NART-Barona estimated IQs ranged from .76 to .87. Estimated NART-Barona IQs were similar for CHI patients and matched controls. The discrepancy between estimated IQs and obtained WAIS-R IQs was significantly less for the combined NART-Barona method than for the Barona et al. (1984) estimation equations.
CHAPTER I

Introduction

Whether for clinical, legal, or research purposes, it is often necessary to ascertain the presence of intellectual deterioration relative to an individual's functioning prior to an injury or illness (Lezak, 1983; Wilson & Stebbins, 1991). While normative data can convey information about an individual’s standing relative to an appropriate reference group, such information is of little use in determining if abilities have declined since the onset of the injury or illness in question (Reitan & Davison, 1974). Knowledge of prior functioning thus becomes vital for determining the presence of deterioration. Ideally, this is accomplished by comparing an individual’s current performance on a standardized intelligence test with test scores obtained before the onset of neurological impairment. Since such information is rarely available among members of the general population, premorbid functioning must routinely be estimated.

The difficulty of establishing an estimated level of premorbid intellectual functioning has long been recognized (Wechsler, 1958; Yates, 1956). Subjective estimates of premorbid functioning based on clinical interview data (e.g. educational level, occupation) rely primarily on clinical judgement, past experience with similar populations, and intuition (Golden, 1978; Golden, Zillmer, & Spiers, 1992;
Gregory, 1987). These estimates are often unreliable; therefore, the development of more objective means for estimating premorbid intelligence has been the focus of much research in neuropsychology.

Historical Basis of Estimating Premorbid Intelligence

The discrimination between persons with intellectual losses versus non-impaired individuals has been the subject of research for almost five decades. Most classification attempts were based on the discrepancy between current measures of intellectual functioning and assumed levels before the onset of impairment. In 1944, Wechsler presented his initial conceptualization of the Wechsler-Bellevue "Deterioration Index" (Wechsler, 1944). This early attempt to identify brain-damaged individuals was based on subtests thought to be differentially affected by the aging process. "Hold" subtests, those unaffected by normal aging, were contrasted with "Don’t-Hold" subtests, those showing normal age-related decline. Organic impairment was suspected when the "Hold-Don’t Hold" difference exceeded that normally exhibited.

With the publication of the Wechsler Adult Intelligence Scale in 1955 (WAIS; Wechsler, 1955), the WAIS "Deterioration Quotient" was presented as a tool for the use in diagnosing brain damage (Wechsler, 1958). The composition and definition of the "Hold" and "Don’t Hold" subtests were modified from the 1944 formulation. The WAIS
"Hold tests" included Vocabulary, Information, Picture Completion, and Object Assembly. Digit Span, Similarities, Block Design, and Digit Symbol comprised the "Don't Hold" tests. An individual's premorbid level of intellectual functioning was inferred from the "Hold" subtests, those in which performance was thought to be stable in spite of cerebral dysfunction, and contrasted with current level of intellectual functioning as measured by subtests that "Don't Hold". On the "Don't Hold" tests, level of performance was hypothesized to decrease in the presence of organic cerebral pathology.

Numerous literature reviews strongly refute the use of comparing subtests that allegedly "hold up" versus those subtests that "don't hold up" as an aid in diagnosing organic cerebral pathology (Frank, 1983; Gregory, 1987; Matarazzo, 1972; Vogt & Heaton, 1977). While some studies showed that the WAIS deterioration quotient discriminated brain-damaged patients from normals (Bersoff, 1970; Vogt & Heaton, 1977), other studies revealed its failure to differentiate patients with organic impairment from those with psychiatric symptomatology (Bersoff, 1970; Crookes, 1961). Revised ratios based on Wechsler subtests have not improved the discrimination of brain-damaged from normal individuals (DeWolfe, Barrell, Becker, & Spaner, 1971; WooSam, Zimmerman, & Royal, 1971). In the few studies in which
brain-damaged individuals were successfully identified, the results could not be replicated (Watson, 1972).

Furthermore, Russell (1972) showed that all subtests of the WAIS are affected by brain damage, not just the "Don't Hold" subtests. The strength of the relationship between brain impairment and performance does vary from subtest to subtest. However, the pattern of variation does not follow that of the Wechsler (1958) deterioration quotient.

Despite the critical literature reviews refuting the use of subtests that allegedly "hold up", current textbooks (i.e. Gregory, 1987; Lezak, 1983) still recommend, albeit cautiously, the use of a patient's highest Wechsler subtest score to estimate the level of premorbid intelligence and the lowest subtest score to estimate intellectual losses secondary to cerebral impairment. More recently, Matarazzo and colleagues (Matarazzo, Daniel, Prifitera, & Herman, 1988; Matarazzo & Prifitera, 1989) cautioned against determining an individual's premorbid level of general intelligence on the basis of highest subtest score. They emphasize the psychometric properties of the Wechsler Adult Intelligence Scale-Revised published in the manual (WAIS-R; Wechsler, 1981), particularly the patterns of inter-subtest scatter in the standardization sample. They note that 48.7% of the sample showed a difference of 7 or more points between their highest and lowest subtest score; 86.1% showed a range of 5 or more points of intersubtest scatter.
Additionally, the clinical significance of subtest scatter must take into account the increase in mean magnitude of subtest scatter in individual WAIS-R protocols as IQ level increases (below 79, mean scatter 5.02; above 120, mean scatter 7.65).

Klesges and colleagues (Klesges, Wilkening, & Golden, 1981; Klesges & Troster, 1987) conclude that decades of research have failed to produce a reliable deterioration quotient and view the "hold-don’t hold" approach as "simplistic and inaccurate" (p.34). They furthermore doubt that modification of the WAIS formulas or generation of a new formula with WAIS-R subtests will produce an improved and reliable deterioration index.

Current Methods of Estimating Premorbid Intelligence

More recently, the estimation of premorbid functioning has relied on (a) measures of present abilities which are highly correlated with intelligence and relatively robust in the absence of focal brain damage, or (b) actuarial methods that use demographic data in a multiple regression equation to determine an index of premorbid intelligence (Crawford, 1989; Klesges, Wilkening, & Golden, 1981; Klesges & Troster, 1987). The first method measures skills, such as vocabulary or reading, which are thought to be stable despite illness or injury. Currently obtained performance is assumed to reflect premorbid ability (Nelson & O’Connell, 1978; Yates, 1956). The second approach involves multiple regression
equations using demographic variables, such as age, sex, and education to compute an estimated premorbid IQ (Barona, Reynolds, & Chastain, 1984; Wilson, Rosenbaum, Brown, Rourke, Whitman, & Grisell, 1978). The research pertaining to these methods of estimating premorbid functioning will be described and evaluated.

Present Ability Estimation

Wechsler Vocabulary Subtest

Lezak (1983) noted that the Wechsler Vocabulary subtest (Wechsler, 1955; 1981) is the "hold" test most commonly used to estimate premorbid intellectual functioning. Although the Vocabulary subtest has the highest correlation with Full Scale IQ (FSIQ; Wechsler, 1955; 1981), its stability in the presence of cerebral pathology is questionable. Numerous studies have found that Vocabulary performance of neurological patients is significantly lower than that of healthy subjects and non-neurological patients. However, most of the early studies failed to control for the influence of demographic factors that are known to impact vocabulary skills, such as age and years of education (Matarazzo, 1972).

For example, Vogt and Heaton (1977) found Vocabulary performance of neuropsychologically impaired subjects was significantly lower than that of unimpaired subjects (p<.001). This difference, however, may have resulted from the significant difference in educational level for the two
groups (impaired, 11.9 years; not impaired, 13.9 years; p<0.01). Russell (1972) found similar differences in an age-matched hospitalized patients. However in this study, the brain-damaged group, not only had significantly less education, but also included congenitally brain-damaged subjects.

Nelson and McKenna (1975) constructed a regression equation to estimate WAIS FSIQ from the WAIS Vocabulary age-corrected scale score. The estimated FSIQ was significantly higher for normal subjects than for dementia patients (p<.001), suggesting that Vocabulary skills do not "hold" among people with dementia. The educational level of the two groups was not presented, thus leaving unanswered the possible effect of years of education on the results reported.

In more methodologically sound studies that controlled for the possible effects of age and education, WAIS FSIQ estimated from WAIS Vocabulary scale score for patients diagnosed with dementia of the Alzheimer’s type (DAT) was significantly lower than that of controls (Hart, Smith, & Swash, 1986). Similar results, indicating that vocabulary skills were not stable, were reported for other neurological disorders, such as multi-infarct dementia (MID), alcoholic dementia, Huntington’s disease, and Korsakoff’s syndrome (Crawford, Parker, & Besson, 1988).
In summary, performance on the Wechsler Vocabulary subtest does not appear to be resistant to cerebral pathology. While the Wechsler Vocabulary subtest is highly correlated with FSIQ in normal individuals, when used as a "hold" test or measure of present abilities it may seriously underestimate premorbid functioning. Although the Vocabulary subtest has been commonly used as a means of predicting premorbid intelligence, Crawford, Parker, and Besson (1988) conclude that it "cannot be validly used for this purpose in the majority of organic groups examined" (p.181).

National Adult Reading Test Performance

Based on the relationship between reading ability and general intelligence level found in normal adults, Nelson and McKenna (1975) proposed that oral reading tests could be used to estimate premorbid intelligence for patients with diffuse cerebral dysfunction. Reading ability, as measured by the Schonell Graded Word Reading Test, (SGWRT; Schonell, 1942), was used to compare dementia patients and normal controls. While mean WAIS scales were significantly lower in the demented group (p<.001), no significant difference between the groups was found for reading performance. Similar results were found by Ruddle and Bradshaw (1982), suggesting that single word oral reading tests have potential as a means of estimating premorbid intelligence.
Nelson constructed what was initially called the New Adult Reading Test (Nelson, unpublished) to correct for the ceiling effect found when using the SGWRT. This test was subsequently renamed and published as the National Adult Reading Test (NART; Nelson, 1982). After the publication of the NART manual (1982), the NART was widely used to estimate premorbid intelligence in clinical and research settings, including studies of cognitive and memory impairment with chronic alcoholics (Acker, Jacobson, & Lishman, 1987), Parkinson’s disease patients (Oyebode, Barker, Blessed, Dick, & Britton, 1986), depressed patients (McKenna & Pratt, 1983), and dementia patients (Kopelman, 1985, 1986; McCarthy, Gresty, & Findley, 1985).

The NART consists of 50 words listed in order of increasing difficulty, which are read aloud by the subject. The vast majority of words are short in length so subjects do not have to analyze complex visual stimuli. All the words are irregular; that is, they do not follow normal grapheme-phoneme correspondence rules (e.g. ache, debt, simile). Irregular words are used to maximize the importance of previous familiarity with the words and to minimize dependence on present ability to apply phonetic rules to yield the correct pronunciation. Therefore, it has been argued that successful test performance requires familiarity with the words but makes minimal demands on current cognitive capacity (Nelson & O’Connell, 1978).
The psychometric properties of the NART include split-half reliability coefficients ranging from 0.90 to 0.93 (Crawford, Stewart, Garthwaite, Parker, & Besson, 1988; Nelson, 1982). The test-retest reliability, with a 10 day delay between administrations, was .98 (Crawford, Parker, Stewart, Besson, & De Lacey, 1989). A factor analytic study by Crawford, Stewart, Cochrane, Parker, and Besson (1989) showed that the NART loaded very highly (0.85) on "g", the first unrotated principal component; thus emphasizing the validity of the NART as a measure of intelligence.

Regression equations were developed for the estimation of WAIS IQ scales from NART errors (Nelson & O'Connell, 1978). The seven WAIS subtests used to develop the equations were Vocabulary, Digit Span, Arithmetic, Similarities, Picture Completion, Block Design, and Picture Arrangement. The equations to estimate WAIS Full Scale IQ (FSIQ), Verbal IQ (VIQ), and Performance IQ (PIQ) are as follows:

Estimated FSIQ = 128 - 0.83(NART errors)
Estimated VIQ = 129 - 0.92(NART errors)
Estimated PIQ = 124 - 0.65(NART errors)

In the standardization sample, the NART predicted 55%, 60%, and 32% of the variance in WAIS FSIQ, VIQ, and PIQ, respectively. Standard errors of estimate were FSIQ 7.6, VIQ 7.6, and PIQ 9.4. In a cross-validation study, Crawford, Parker, Stewart, Besson, and De Lacey (1989)
reported that NART performance accounted for even more variance (FSIQ, 66%; VIQ, 72%; PIQ, 33%). This increase was attributed to the use of all WAIS subtests instead of only seven subtests used originally by Nelson and O'Connell (1978).

If the NART is to be used in the estimation of premorbid intelligence, the stability of NART performance in normal aging must be ascertained. In general, studies which examined the effect of age on reading ability found that NART performance did not decline with increasing age, with non-significant correlations ranging from 0.6 to 0.14 reported by Nelson (1982) and Crawford, Parker, Stewart, Besson, and De Lacey (1989). Although Crawford, Stewart, Garthwaite, Parker, and Besson (1988) reported a small but significant correlation (.18, p<.01) between NART errors and age, the correlation was no longer significant after education and socio-economic status were partialled out. Further evidence of the stability of NART performance comes from a large epidemiological study of elderly women in which cognitive decline was noted with increasing age, yet NART performance remained stable (Brayne & Beardsall, 1990).

Crawford, Stewart, Garthwaite, Parker, and Besson (1988) investigated the possibility that NART performance improved in early adulthood and then declined in old age. Neither age nor polynomial functions of age were significantly correlated with NART performance, indicating
no evidence of a curvilinear relationship. Overall, it appears that reading ability as measured by the NART is resistant to deterioration with normal aging.

Numerous investigations support the view that NART performance is stable in neurological disorders and constitutes a useful estimator of premorbid intelligence. Crawford, Parker, and Besson (1988) evaluated NART performance in a number of organic conditions in which cortical atrophy or other neuropathological features were predominant. When compared to healthy controls matched for age, sex, and years of education, NART performance of the DAT, multi-infarct dementia (MID), alcoholic dementia, and closed head injured (CHI) groups did not differ significantly from their matched control group.

Since a major symptom and a diagnostic criterion of dementia is a significant decline in measured intelligence, the stability of NART performance in dementia has received considerable attention. In an early study, Nelson and O'Connell (1978) found that hospitalized dementia patients were severely impaired on the WAIS when compared to the NART standardization sample (p<.001). In contrast, NART performance of the two groups was not significantly different. For the dementia patients, the difference between NART estimated IQ and obtained WAIS IQ was significantly greater than the difference for the controls for all three IQ scales.
These preliminary results led to further research that exercised better control over extraneous variables that might have influenced the findings. In later studies in which groups of dementia patients were matched for age, sex, and education with unimpaired controls, the stability of NART performance in dementia was upheld (Nebes, Martin, & Horn, 1984; Schlosser & Ivison, 1989).

Hart et al. (1986) found the discrepancy between NART estimated and actual obtained WAIS FSIQ was significantly greater for 20 hospitalized DAT patients than for 15 unimpaired elderly controls (p<.001). Furthermore, 16 of the 20 DAT patients had a greater than 5 percent discrepancy between NART estimated and obtained WAIS FSIQ, while none of the normal group obtained a discrepancy of this magnitude. However, the small sample size in this study cautions against the generalizability of these results.

Several studies investigated the relationship between dementia severity and NART performance. O'Carroll and Gillear (1986) observed no difference in NART performance for clinically diagnosed mild and moderate dementia patients, suggesting that the NART is a "dementia-insensitive" measure (p.157). A longitudinal investigation using the same group of dementia patients noted significant increases in severity of cognitive impairment after a one year delay. However, NART performance had not significantly declined (O'Carroll, Baikie, & Whittick, 1987).
In contrast, other studies indicated that NART performance may not be entirely resistant to the progression of dementia. Stebbins, Wilson, Gilley, Bernard, and Fox (1990) divided DAT and/or MID patients into very mild, mild, and moderate groups based on performance on the Mini-Mental State Exam (Folstein, Folstein, & McHugh, 1975). NART scores did not differ for the very mild group and the normal elderly subjects. However, the other groups (mild, moderate) had significantly lower performance on the NART than the normal unimpaired control subjects. The authors concluded that the NART performance does not appear entirely resistant to decline as level of dementia severity increases. However, this finding does not argue against the use of the NART for early diagnosis of dementia because the NART performance is stable in the very mild stage of dementia, the stage which is most problematic for diagnosis. Identifying intellectual decline is especially important for early diagnosis only, since patients with more advanced dementia can usually be identified with mental status tests (Pfeffer et al., 1981; Roth et al., 1986).

The studies presented thus far are concerned with the utility of the NART as an estimator of premorbid WAIS IQs. The revision of the WAIS in 1981 raised the question of the appropriateness of the NART as a means to estimate WAIS-R IQ scales. Only two studies have addressed this issue. Sharpe and O’Carroll (1991) developed regression equations to
estimate WAIS-R FSIQ and VIQ from NART error score, using methodology similar to that used to develop the WAIS equations. The revised regression equations accounted for 59% of the variance in FSIQ and 65% of VIQ variance, comparable to that obtained by Nelson and O'Connell (1978) using the original NART equations. Cross-validation with a group of elderly dementia patients showed no differences in the number of NART errors for demented and non-impaired subjects. The NART estimated WAIS-R IQs, however, were significantly higher than obtained IQs for the demented group. The authors concluded that the ability to pronounce irregular words correctly remains relatively unimpaired in dementia, making the NART a useful tool to estimate WAIS-R premorbid IQ for Canadian subjects.

Ryan and Paolo (1992) developed and cross-validated regression equations to estimate WAIS-R IQs from NART error scores for an elderly American population. The development sample and the cross-validation sample were at least 75 years of age with no medical or psychiatric disorder that would interfere with cognitive functioning. Subjects completed the full WAIS-R and the NART. Preliminary equations demonstrated accurate estimation of IQs in the cross-validation group; therefore, new equations were develop using the entire normal sample (n=126). The equations to estimate WAIS-R IQs are as follows:
NART FSIQ = 131.3845 + (NART errors)(-1.124)
NART VIQ = 132.3893 + (NART errors)(-1.164)
NART PIQ = 123.0684 + (NART errors)(-0.823)

Standard errors of estimate were 8.83, 7.70, and 12.08 for FSIQ, VIQ, and PIQ, respectively. Additional cross-validation on a sample of 20 elderly, neurologically impaired patients indicated that NART estimated IQs were significantly higher than obtained WAIS-R IQs (p<.001), demonstrating that intellectual deterioration had occurred in these patients.

In summary, NART performance appears to be resistant to deterioration in normal aging and early stages of dementia. Regression equations to estimate premorbid IQ using NART errors seem to accurately estimate WAIS IQ in non-impaired individuals and brain-damaged patients. The almost exclusive use of dementia patients in the validation studies, however, leaves in question the accuracy of these equations for patients with other neurological disorders. NART based regression equations to estimate WAIS-R IQs hold promise, although more studies of NART performance are clearly required before the NART can be used with confidence to estimate premorbid intelligence.

Demographic Estimation

WAIS Regression Equations

A number of demographic variables have a reasonably strong relationship with intelligence, so current IQ test
performance is often examined for consistency with educational and occupational history data obtained during the clinical interview (Matarazzo, 1972). Two early attempts to estimate premorbid IQ from demographic variables involved assigning subjects to one of four educational categories (Fogel, 1964; Ladd, 1964). WAIS FSIQs of the hospitalized non-neurological patients were used as premorbid IQ estimates for the education-matched neurologically impaired subjects. The difference between expected and obtained IQ was used to differentiate organically impaired patients from neurotics or medical inpatients. Approximately 70% of patients were correctly identified as brain-impaired, an improvement of 6% over base rate. Although these early studies failed to control for the influence of age and socio-economic status variables, the results suggest that premorbid IQ estimation based on demographic information may have merit.

Wilson et al. (1978) sought to use demographic variables in a more systematic and objective manner. The relationship between intelligence and demographic variables was explored using multiple regression techniques. They reasoned that adult onset neurological dysfunction should have little effect on demographic status. Therefore, the accuracy of regression equations to estimate IQs should be limited only by the correlation between IQ and the demographics variables. WAIS FSIQ, VIQ, and PIQ scores from
1700 subjects in the WAIS standardization sample were regressed in a stepwise procedure on five variables (age, sex, race, education and occupation). The following regression equations to estimate premorbid IQ were obtained:

Estimated FSIQ = 74.05 + .17(Age) - 1.53(Sex) - 11.33(Race) + 2.97(Education) + 1.01(Occupation)

Estimated VIQ = 70.80 + .18(Age) - 2.02(Sex) - 8.99(Race) + 3.09(Education) + .97(Occupation)

Estimated PIQ = 81.55 + .14(Age) -.66(Sex) - 12.91(Race) + 2.44(Education) + .91(Occupation)

Age and education were treated as continuous variables. The remaining demographic factors were coded as follows: Sex: Male = 1, Female = 2; Race: White = 1; Nonwhite = 2; Occupation: Professional and technical workers = 5; Farmers and farm managers = 1; Managers, officials, and proprietors = 7; Clerical and sales workers = 7; Craftsmen and foremen = 6; Operatives = 3; Private household workers = 3; Service workers = 5; Farm laborers = 0; Laborers = 1; Keeping house = 4; Students = 10; Others (disabled, unemployed, retired) = 0. The equations generated by this procedure predicted 54%, 53%, and 42% of the variance in WAIS FSIQ, VIQ, and PIQ respectively. The standard errors of estimate were FSIQ, 10.2; VIQ, 10.2; PIQ, 11.4.

Education was the single best predictor of IQ for all of the WAIS scales, although the remaining demographic variables significantly improved predictive accuracy at
subsequent steps of the analysis. The addition of the other four variables to education increased the amount of explained IQ variance by about 10%. Wilson et al. (1978) noted that mean education level had increased in the 20 years since the standardization data was collected from 10.1 years in 1955 to 12.3 years in 1975. They suggested that the accuracy of estimated premorbid IQ might be improved by adjusting the education weights in the equations to the 1955 level by multiplying the weights by .82.

Wilson, Rosenbaum, and Brown (1979) compared the ability of the demographic method of estimating premorbid IQ (Wilson et al., 1978) and the present abilities method (WAIS "Hold tests") to classified brain-impaired and nonimpaired subjects. Each method was used as the premorbid estimate of WAIS FSIQ in the Wechsler (1958) deterioration quotient. The deterioration quotient using the demographic estimation of premorbid IQ was 11% more accurate than the original Wechsler (1958) quotient (61% versus 72%, respectively).

Following publication of these studies, the Wilson et al. (1978) equations were routinely used in research as a means of determining the premorbid comparability of clinical groups (Baird et al., 1984; Bayles & Tomoeda, 1983; Hamsher & Roberts, 1985; Weingartner, Grafman, Boutelle, Kaye, & Martin, 1983).

In an early cross-validation study, Klesges, Sanchez, and Stanton (1981) examined the correlations between
demographically estimated IQ and obtained WAIS IQ in two neurologically unimpaired clinical samples. Highly significant correlations between estimated and obtained IQ were found in both groups (p<.001). However, the proportion of FSIQ variance accounted for was lower than expected (41% psychiatric inpatient sample; 25% outpatient sample). These authors found that the demographic equations significantly overestimated FSIQ in both samples, and encouraged the use of the Wilson et al. (1978) educational correction.

In a further study, Klesges, Fisher, Vasey, and Pheley (1985) compared the Wilson et al. (1978) original and educationally adjusted formulas. Significant overestimation of WAIS IQs using the original formula was reported for both the brain-impaired and normal groups (p<.001). No improvement was found when the educationally adjusted formula was used. These unfavorable results were consistent for FSIQ, VIQ, and PIQ. Klesges et al. (1985) maintained that "future uses of the Wilson et al. (1978) formulae should probably be restricted to research purposes for the present time" (p.2).

Bolter, Gouvier, Veneklasen, and Long (1982) evaluated the utility of the Wilson et al. (1978) FSIQ formula for head injured patients. The Halstead-Reitan battery and the WAIS were administered in serial evaluations. Patients were divided into two groups on the basis of whether neuropsychological test results at second testing indicated
that they had recovered or were still impaired. It was assumed that, for patients whose neuropsychological test performance had returned to normal at the second evaluation, IQ scores obtained at that time would be a reasonable estimate of premorbid intelligence. The control group was composed of "pseudoneurological" patients who were evaluated for suspected neurological impairment, but were diagnosed as non-impaired neurologically. The correlation between estimated and obtained FSIQ at final evaluation in these groups ranged from .68 for the recovered and non-recovered groups (p<.05) to .73 for the controls (p<.01). The accuracy of the estimated premorbid IQ was evaluated according to the guidelines of Klesges et al. (1981). That is, estimated IQ scores that fell within one standard error of estimate of the obtained IQ score were defined as accurate for the controls and recovered patients; estimated IQ outside one standard error of estimate was the accuracy criterion for the non-recovered patients. Bolter et al. (1982) reported that overall the predictive accuracy of the Wilson et al. (1978) equation was unimpressive, with approximately 50% accuracy for brain-damaged patients. There was little improvement noted when the educationally adjusted formula was employed. These authors argued that while the Wilson et al. (1978) formulas may be useful for research purposes, they were not sufficiently accurate to justify clinical application with head trauma patients.
A second study by this group, Gouvier, Bolter, Veneklasen, and Long (1983) examined the same issues with the same patients, but reported comparisons between predicted and obtained VIQ and PIQ (rather than FSIQ). Essentially similar results were obtained. The educational adjustment did not significantly improve the predictive accuracy of either the VIQ or PIQ estimations. These authors again cautioned against the clinical application of the formulas.

Goldstein, Gary, and Levin (1986) evaluated the accuracy of the Wilson et al. (1978) equations for clinical patients referred for neuropsychological or psychological assessment. Rigorous attempts were made to exclude subjects liable to be intellectually impaired. Goodness of fit tests found an "adequate overall fit" between estimated and obtained FSIQ. However, the formula tended to overestimate FSIQ for patients with an IQ of 75 and below and to underestimate IQ in those with an IQ of 120 and above, leading Goldstein et al. (1986) to conclude that "the formulas may work best in clinical settings with patients whose IQ values are neither extremely high nor unusually low" (p.411).

The purpose of demographic equations is not to estimate the current IQ scores of clinical subjects, but to estimate their premorbid IQ, the IQ level that would have been obtained had medical or psychiatric difficulties not
developed. Initial cross-validation studies should have also included healthy, normal subjects in order to eliminate the possibility of intellectual deterioration in the cross-validation samples. Karzmark, Heaton, Grant, and Matthews (1985) sought to correct this oversight by conducting a methodologically sound, cross-validation study using a sample of 491 healthy, unimpaired subjects with no history of neurological disease, head trauma, or substance abuse. Mean estimated FSIQ corresponded closely with mean obtained FSIQ (110.9 versus 112.8). The accuracy of the Wilson et al. (1978) formula was relatively stable across different levels of age, education, and occupation. However, this was not so for intellectual levels. The formula was less accurate in the high and low ranges, again reflecting the limitations of the Wilson et al. (1978) method of estimating Full Scale IQ.

In summary, despite the moderate correlations between predicted and obtained WAIS IQ, the above studies seem to cast doubt on the validity of the demographic approach to estimate premorbid IQ for the individual patient. However, the reliance on clinical cross-validation samples in most of these studies may have engendered this unnecessarily pessimistic conclusion. The use of clinical cross-validation samples makes it impossible to rule out the presence of intellectual impairment in these samples. These "normal" subjects were all referred for neuropsychological
evaluation, presumably because cognitive deficits were suspected. Furthermore, some cross-validation samples assumed to be neurologically normal included psychiatric inpatients diagnosed with some form of schizophrenia (Klesges, Sanchez, & Stanton, 1981) or persons involved in diving accidents and electrocutions (Goldstein et al., 1986). The one study using healthy, unimpaired subjects upheld the utility of the demographic approach for all but the extreme ranges of intelligence (Karzmark et al., 1985).

The moderate success of the WAIS equations prompted Reynolds and Gutkin (1979) to develop demographic formulas to estimate intellectual levels in children using the Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) as the criterion measure. Since this review is focused on adult premorbid indices, the child regression equations will not be discussed. For information on the regression equations predicting WISC-R IQ, the reader is referred to original articles and literature reviews (Klesges, 1982; Klesges & Sanchez, 1981; Klesges & Troster, 1987; Klesges, Wilkening, & Golden, 1981; Reynolds & Gutkin, 1979).

**WAIS-R Regression Equations**

With the introduction of the Wechsler Adult Intelligence Scale - Revised (WAIS-R; Wechsler, 1981), the Wilson et al. (1978) formulas became an inappropriate method of estimating premorbid levels of intelligence (Klesges &
Troster, 1987). Due to changes in content and renorming procedures, the WAIS-R generated IQ scores that averaged approximately seven points lower than that generated by the WAIS (Wechsler, 1981). New IQ prediction formulas were therefore needed to compensate for these changes.

Barona et al. (1984) used a methodology similar to that of Wilson et al. (1978) to develop demographic regression equations for the estimation of premorbid WAIS-R IQ. Predictor variables from the WAIS-R standardization sample (N=1,880) included those used in the original WAIS regression equations (age, sex, race, education, and occupation) plus variables for urban/rural residence and geographical region. The regression equations developed to estimate WAIS-R IQ scales are as follows:

Barona FSIQ = 54.96 + .47(age) + 1.76(sex) + 4.71(race) + 5.02(education) + 1.89(occupation) + .59(region)

Barona VIQ = 54.23 + .49(age) + 1.92(sex) + 4.24(race) + 5.25(education) + 1.89(occupation) + 1.24(residence)

Barona PIQ = 61.58 + .31(age) + 1.09(sex) + 4.95(race) + 3.75(education) + 1.54(occupation) + .82(region)

The variables were coded as follows: Sex: Male = 2, Female = 1; Race: Black = 1, Other = 2, White = 3; Residence: Urban = 2, Rural = 1; Region: South = 1, North Central = 2, Western = 3, Northeast = 4; Age: 16-17 = 1, 18-19 = 2, 20-24 = 3, 25-43 = 4, 35-44 = 5, 45-54 = 6, 55-64 = 7, 65-69 = 8, 70-74 = 9; Education: 0-7 years = 1, 8 years = 2, 9-11
years = 3, 12 years = 4, 13-15 years = 5, 16+ years = 6; Occupation: Professional and technical = 6, Manager, Officials, Proprietors, Clerical, and Sales workers = 5, Craftsmen and Foreman (skilled) = 4, Not employed = 3, Operatives, Service workers, Farm managers (semiskilled) = 2, Farm laborers, Farm foreman, and Laborers (unskilled) = 1.

In these equations, the most powerful predictors of IQ were education, race, and occupation. However, all variables in the final equations contributed significantly to the explained variance in estimating premorbid intelligence (p < .01). The total variance accounted for by these equations was 38%, 24%, and 36% for VIQ, PIQ, and FSIQ respectively. The standard errors of measurement were VIQ, 11.79; PIQ, 13.23; and FSIQ, 12.14. Despite the use of more current norms in generating these equations, the Barona et al. (1984) equations accounted for substantially less IQ variance and had larger standard errors of measurement than the Wilson et al. (1978) equations.

The Wilson et al. (1978) and Barona et al. (1984) formulas were compared by Sweet, Moberg, and Tovian (1990). Additionally, the Wilson et al. (1978) estimated IQs were calculated with an eight point reduction in order to increase their accuracy as predictors of WAIS-R IQs (as suggested by Karzmark et al., 1985). For both psychiatric and brain-damaged patients, the Barona et al. (1984)
estimates were more accurate than the original Wilson et al. (1978) estimates; but the corrected Wilson et al. (1978) estimates equaled or exceeded the accuracy of the Barona et al. (1984) formulas. Significant overestimation of the WAIS-R IQ scales was obtained by all three methods (p<.001), leading Sweet et al. (1990) to conclude that while the demographic method of estimating premorbid intellectual ability is more accurate than "Hold-Don't Hold" deterioration ratios, its use with individual patients is not recommended.

In a cross-validation study of the Barona et al. (1984) formulas, Eppinger, Craig, Adams, and Parsons (1987) divided subjects into "neurologically normal" and "brain-damaged" groups by data from biomedical tests. Correlations between estimated and obtained IQs for the neurologically normal sample yielded significant coefficients of .78, .60, and .76 for VIQ, PIQ, and FSIQ, respectively. Estimated WAIS-R IQ scores were significantly larger than obtained scores in the brain-damaged group (p<.001). However, the neurologically normal group also had significantly larger estimated than obtained IQs. Eppinger et al. (1987) explained that the differences between estimated and obtained IQs in the normal group may have been due to existing psychological problems that could have lowered current intellectual functioning.

Eppinger et al. (1987) also examined the clinical utility of the formulas to discriminate between
neurologically normal and brain-injured populations by calculating discrepancy scores (D-score = IQ estimated - IQ obtained) for all subjects. Mean discrepancy scores in the neurological group were significantly larger (p<.0001) than in the non-neurological group. However, the D-score cut-off method produced only slightly higher rates of correct patient classification than obtained WAIS-R IQ scores alone.

In an attempt to improve the accuracy of demographic estimation of intelligence, Barona and Chastain (1986) eliminated two subgroups from the original WAIS-R standardization sample and developed regression equations for the remaining subjects. The first subgroup deleted included subjects between 16 and 19 years of age. Because they were not yet employed in full-time occupations, the occupational classification of these subjects was that of their head of household. This classification of occupational status was misleading and may have resulted in inaccurate estimates of premorbid IQ for these subjects. The second subgroup deleted consisted of races other than black or white. Because of the low representation of "other" races in the standardization sample, coding them for inclusion in the analysis might inflate error variance. The same predictor variables used in the Barona et al. (1984) equations were again employed. However, in calculating premorbid IQ, age and education are treated as continuous
variables; the other variables were coded (see Barona & Chastain, 1986).
The revised equations to predict IQ are as follows:

Estimated FSIQ = 44.34 + 2.73(education) + 0.16(age) + race
+ sex + occupation + region

Estimated VIQ = 41.17 + 2.84(education) + 0.16(age) + race
+ sex + occupation + region + residence

Estimated PIQ = 56.57 + 2.07(education) + 0.12(age) + race
+ sex + occupation + region

The total variance accounted for by these equations were
FSIQ, 43%; VIQ, 47%; and PIQ, 28%. The standard errors of
estimate were 11.54, 10.96, and 12.91 for FSIQ, VIQ, and
PIQ, respectively.

Paolo and Ryan (1992) the compared utility of the
Barona et al. (1984) and Barona and Chastain (1986)
equations for elderly adults. The normal group (mean age of
80.48 years) were without evidence of current or past
neurological or psychiatric illness. The neurologically
impaired subjects (mean age 78.65 years) had medically
documented evidence of brain dysfunction. For both the 1984
and 1986 methods, the correlations between actual and
estimated IQs for the normal sample were comparable to those
reported for younger persons (Barona et al., 1984; Eppinger
et al., 1987; Barona & Chastain, 1986). The accuracy of the
predicted IQs was evaluated by calculating the percentage of
obtained IQs which fell within one standard error of
estimate of the estimated IQs. For the normal subjects, FSIQ estimated by the 1984 method had an accuracy rate of 77.3 percent; the 1986 method was 72.0 percent accuracy. As expected, IQs for the neurologically impaired subjects were overestimated by both methods, reflecting intellectual deterioration.

The Barona and Chastain (1986) equations were not found to be more accurate than the Barona et al. (1984) equations and consequently have received no further research interest. Although there have been only a few cross-validation studies of the Barona et al. (1984) formulas, they became widely used in research. For example, Hooker and Raskin (1986) used the FSIQ equation to determine whether the groups of classic and common migraine patients were comparable in terms of premorbid IQ. Similarly, Levin et al. (1987) used the equations to compare head-injured subjects and healthy controls.

In summary, while the demographic method of estimating WAIS-R intelligence seems promising, several limitations argue against its use with individual clinical patients. A major limitation of the Barona et al. (1984) equations is the restricted range of possible IQ estimates. For example, WAIS-R FSIQ estimates range from a base of 69 to a ceiling of 120, although extreme values will rarely be calculated. The lowest estimated IQs can be calculated only for a 16 to 17 year old, black female who resides in a rural area of the
south, has zero to seven years of education, and is employed as a laborer. The highest estimated IQs are relevant only for a 70 to 74 year old white male professional with 16 or more years of education who resides in an urban area of the northeastern United States. Barona et al. (1984) cautioned that premorbid FSIQ estimates may be seriously over-or under-estimated in persons whose actual premorbid FSIQ was above 120 or below 69. Others concur that the Barona et al. (1984) method of estimating premorbid intelligence is not recommended for exceptional individuals such as the gifted, mentally retarded, or even slow learners from special education programs (Eppinger et al., 1987).

In addition, the rather large standard errors of estimate suggest that estimates of premorbid intelligence for individual patients may not be very accurate. For example, for an estimated FSIQ of 100, scores within the standard error of estimate range from 88 to 112, or from the low average range to the high average range of intellectual functioning. The development of more accurate formulas is clearly needed before premorbid levels of intelligence can be estimated with confidence for the individual patient.

Conclusion

There are two main approaches to the estimation of premorbid intelligence, the present abilities method and the demographic estimation method. The present abilities method relies on measures of present abilities, such as vocabulary
or reading, that are thought to be relatively robust in the absence of focal brain damage. The demographic approach involves the application of multiple regression techniques to demographic data.

The Wechsler Vocabulary subtest (Wechsler, 1955; 1981) was the most commonly used present abilities measure of premorbid intelligence. Although this subtest has the highest correlation with FSIQ, its stability in the presence of cerebral dysfunction is questionable. Numerous studies have shown that Vocabulary skills do not appear to be resistant to cerebral pathology, and when used as a measure of present abilities, it may seriously underestimate premorbid functioning.

The NART is an oral reading test of 50 short irregular words. Most studies concur that the ability to read non-phonetic words appears to be resistant to deterioration in normal aging and early stages of dementia. Regression equations to estimate premorbid IQ using NART errors seem to accurately estimate WAIS IQ in non-impaired individuals and brain-impaired patients. Regression equations to estimate WAIS-R IQs seem promising, although more studies of NART performance, especially with other neurological disorders, are clearly required before the NART can be used with confidence as a valid estimator of premorbid intelligence.

The demographic method of estimating premorbid intelligence has a distinct advantage in that estimates
based on demographics are not affected by neurological injury or illness, as current abilities measures may possibly be. The Wilson et al. (1978) formulas to estimate WAIS IQ scores used five demographic variables (age, sex, race, education, and occupation) in multiple regression equations. While moderate correlations between estimated and obtained IQs were noted, the reliance on clinical cross-validation samples cast doubt on the accuracy of the estimates for the individual patient. Furthermore, the publication of the revised WAIS rendered the Wilson et al. (1978) formulas obsolete.

The Barona et al. (1984) formula is the most commonly used demographic method to estimate WAIS-R IQs. Regression equations use the variables of age, sex, race, education, occupation, geographical region, and urban/rural residence to estimate IQ. A serious limitation of the Barona et al. (1984) regression equations includes the inability to estimate WAIS-R IQs at the extremes of the normal curve distribution and a bias toward estimating in the middle ranges of intelligence (low average, average, high average). The probability of overestimating or underestimating IQs within certain populations is problematic (e.g. mentally retarded, gifted). The proportions of variance accounted for, together with the large standard errors of estimate, suggest that estimates of premorbid intelligence for individual patients may not be very accurate.
Rationale

The literature enumerates limitations of both the NART present abilities approach and the Barona et al. (1984) demographic method, and argues against their use for estimating premorbid intelligence for individual patients. The use of the NART as an estimator of premorbid intelligence is problematic for several reasons. A primary concern is that the Nelson and O'Connell (1978) formulas were based on a short form (seven subtests) of the WAIS. FSIQ, as well as VIQ and PIQ, were prorated from less than two-thirds of the WAIS subtests. Test data based on prorated scores is subject to serious questions of reliability (Wechsler, 1958; Matarazzo, 1972; Lezak, 1983). A number of studies suggest that shortened versions of the WAIS tend to overestimate FSIQ, are not as sensitive to the effects of generalized intellectual impairment, and are best used for screening purposes only (Margolis, Taylor, & Greenlief, 1986; Roth, Hughes, Monkowski, & Crossen, 1984; Ryan, Georgemiller, & McKinney, 1984). A second limitation of the NART method is that it was developed to predict WAIS IQs. The revision of the WAIS raised the question of the appropriateness of the NART method as a means to estimate WAIS-R IQs. Only two recent studies have investigated the utility of the NART as an estimator of WAIS-R IQs; one with a Canadian population (Sharpe & O’Carroll, 1991), the other with an American elderly population (Ryan & Paolo, 1992).
A third concern focuses on the almost exclusive use of demented subjects in the validation studies. The stability of NART performance in patients with other neurological disorders is still unanswered. This is especially the case for closed head injured patients for which only one study was completed (Crawford, Parker, & Besson, 1988). Finally, the NART was developed and standardized in Great Britain. If the NART is to be used in the United States, normative data from an American sample using North American pronunciation rules are needed. In the only study addressing this issue, Ryan and Paolo (1992) developed regression equations to predict WAIS-R IQs in elderly Americans. While the NART appears to be stable in normal aging (Brayne & Beardsall, 1990; Crawford, Parker, Stewart, Besson, & De Lacey, 1989), the validity of these equations for younger individuals has not yet been ascertained.

The main controversy of the Barona et al. (1984) method focuses on the questionable ability to produce a clinically acceptable estimation of premorbid intelligence in the individual patient. A serious limitation of the Barona et al. (1984) regression equations includes the inability to estimate WAIS-R IQs at the extremes of the normal curve distribution. The formulas can only compute a range of IQ scores with a base of 69 and a ceiling of 120, and is biased toward predicting in the middle ranges of intelligence (low average, average, high average). The proportions of
variance accounted for, together with the standard errors of estimate, suggest that the Barona et al. (1984) IQ estimates may not be very accurate for the individual patient.

If the present abilities method and the demographic estimation method each account for a significant amount of non-overlapping variance in criterion (premorbid IQ), it is not surprising that the combination of the present abilities and demographic variables in regression equations has been suggested as a means to provide a more accurate estimate of premorbid IQ (Bolter et al., 1982; Stebbins et al., 1990). Preliminary data from other countries suggest that this combined approach may represent the procedure of choice. Crawford, Stewart, Parker, Besson, and Cochrane (1989) regressed WAIS IQs from a British sample of 151 non-clinical subjects on NART error score and the demographic variables of age, sex, social class, and education. The resulting regression equations predicted more variance than either the NART or demographic variables alone (73%, 78%, and 39% of the variance in WAIS FSIQ, VIQ, and PIQ respectively). While these equations have not been cross-validated, the results suggest that the combined estimation method has considerable potential. Similarly, Willshire, Kinsella, and Prior (1991) combined NART errors and age, sex, and education variables to estimate prorated WAIS-R IQ in older Australian citizens. The combined regression equation accounted for 56% of the variance in the prorated WAIS-R IQ;
substantially more than the 38% explained by NART errors alone.

This project attempted to improve the accuracy of WAIS-R IQ estimation by exploring a combined present abilities and demographic approach that may partially overcome these limitations. The utility of the combined estimation formulas for closed head injured (CHI) patients was investigated.

While there is general agreement that intellectual functions are impaired following closed head injury, there is considerable controversy in the literature concerning the recovery of intellectual functioning in severe CHI patients (Levin, Benton, & Grossman, 1982; Miller, 1984). Mandleberg and Brooks (1975) found that intellectual functioning improves with time since injury with WAIS IQ scores returning to normal within three years. Other researchers disagree, noting that residual deficits are present for a much longer period of time after injury (Drudge, Williams, Kessler, & Gomes, 1984). Others find the potential for recovery is related to the severity of injury, with prognosis worsening as length of coma and post-traumatic amnesia (PTA) increases (Bond & Brooks, 1976; Jennett & Teasdale, 1981). In a comprehensive review, Levin, Benton, and Grossman (1982) enumerate the many flaws in the CHI recovery literature, including the failure to consider premorbid intellectual functioning in CHI patients.
In order to assess degree of recovery, it is important to determine whether a patient whose intellectual functioning has returned to the normal range was functioning at that level prior to injury or was functioning premorbidly at a higher level (Long & Williams, 1988). Williams, Gomes, Drudge, and Kessler (1984) also emphasize the importance of premorbid intellectual functioning as a predictor of cognitive functioning after injury. They note that this relationship has been widely ignored by researchers, even though premorbid "estimates approach the importance of coma grade as predictors of cognitive functioning" (p. 584).

Given these considerations, this project included a series of two studies. The first study examined the utility of the present abilities approach to estimating premorbid intelligence by focusing on NART performance in severe CHI patients in their first year post injury and matched normal adults below age 75 years. The second study examined whether the accuracy of WAIS-R IQ estimation could be improved by combining the present abilities and demographic approaches. The clinical utility of the new combined regression equations to estimate WAIS-R FSIQ, VIQ, and PIQ was assessed using severe CHI patients in their first year of recovery. These patients typically show significant decreases in intellectual functioning (Mandleberg & Brooks, 1975; Drudge et al., 1984). It is assumed that if regression equations to estimate WAIS-R IQs are clinically
useful for this population, the equations will also be useful for mild CHI patients who typically exhibit less impairment in current level of intellectual functioning.

**Study 1**

The NART regression equations to estimate WAIS-R FSIQ, VIQ, and PIQ (Ryan & Paolo, 1992) were cross-validated on two groups of subjects, younger normal adults and CHI patients. Attempts to correct the limitations of previous research with the NART included administration of all WAIS-R subtests and determination of NART errors using North American pronunciation rules. Both of these changes helped to ensure that the NART was adequately evaluated as an estimator of WAIS-R IQs for an American population. It is assumed that if NART performance remains stable in spite of severe CHI, it would not be affected by less severe injury. Specific hypotheses tested are as follows:

**Hypothesis 1:** Obtained WAIS-R IQs and estimated NART IQs will be significantly correlated in unimpaired subjects.

**Hypothesis 2:** Obtained WAIS-R IQs will be significantly lower in the CHI group than in a matched (age, education, gender, race) control group. Estimated NART IQs for CHI patients and matched unimpaired controls will not significantly differ.

**Hypothesis 3:** The discrepancy between obtained WAIS-R IQs and NART estimated IQs will be significantly greater for CHI patients than for matched unimpaired controls.
Study 2

Regression equations to estimate WAIS-R IQs were developed by combining a stable measure of performance (NART) with the Barona et al. (1984) demographic regression equation. Demographic variables were used to compute the estimated Barona IQ, which was entered as a predictor variable along with NART error score in the multiple regression analysis. The individual predictive value of the demographic variables in determining premorbid IQ was not addressed because the heterogeneity of the standardization sample of the WAIS-R used to develop the Barona et al. (1984) regression equations could not be practically duplicated in this study. Any demographically based method for estimating IQ would yield low correlations when applied to demographically homogeneous samples; whereas higher correlations would be observed for samples that are more demographically diverse. Separate formulas to estimate WAIS-R FSIQ, VIQ, and PIQ were generated. The new combined NART-Barona equations were then cross-validated on another group of non-impaired subjects.

Since correlations between obtained and estimated IQs only indicate the ability to rank subjects into the same ordinal and linear relationships, the accuracy of the new combined NART-Barona equation was also investigated by calculating a discrepancy score that represents the difference between actual obtained WAIS-R IQ and estimated
NART-Barona IQ. The utility of the combined NART-Barona estimation equations was assessed using a clinical sample of severe CHI patients evaluated within one year post-injury.

Hypothesis 1: Obtained WAIS-R IQs and estimated NART-Barona IQs will be significantly correlated in unimpaired control subjects.

Hypothesis 2: Obtained WAIS-R IQs will be significantly lower in the CHI group than in a matched (age, education, gender, race) control group. Estimated NART-Barona IQs for CHI patients and matched unimpaired controls will not significantly differ.

Hypothesis 3: The discrepancy between obtained WAIS-R IQs and estimated NART-Barona IQs will be significantly greater for CHI patients than for matched unimpaired controls.

Hypothesis 4: For unimpaired control subjects, the discrepancy between obtained WAIS-R IQs and the IQs estimated using the NART-Barona formula will be significantly less than the discrepancies found when WAIS-R IQ is estimated using either the NART IQ equations (Ryan & Paolo, 1992) or the Barona IQ equations (Barona et al., 1984).
CHAPTER II

Method

Subjects

The total sample included 100 subjects. All subjects were required to have the physical ability necessary to complete required tasks. For example, individuals with physical limitations such as articulatory or serious visual problems were excluded. Persons who reported an inability to read were also excluded.

Non-clinical Sample

The non-clinical sample included 75 individuals recruited on a volunteer basis from local communities in southern Louisiana. Only subjects who reported no history of head injury, neurological or other medical impairment, drug and/or alcohol abuse, or psychological impairment (e.g., major affective or psychotic disorders) which could possibly have affected intellectual functioning were included. Self-report screening information was assumed to be accurate; no collaborating evidence was obtained. Only one subject was excluded from the study because he reportedly never learned to read.

The non-clinical sample was divided into two groups. Group 1 (Development) was used to generate new linear regression equations to estimate WAIS-R IQs from the appropriate estimated Barona IQ (Barona et al., 1984) plus NART error score. This group was composed of subjects
stratified by age and gender to parallel the WAIS-R standardization sample used in developing the Barona et al. (1984) regression equations. Subjects from the youngest age category (16 to 17 years) were excluded from the present study since their occupational status for the WAIS-R standardization sample was that of their head of household. Inclusion here may have possible resulted in the development of inaccurate regression formulas to estimate premorbid intelligence. Group 1 (Development) included 50 individuals (25 males, 25 females) ranging in age from 18 to 74 years. Mean age was 42.38 (SD=18.79); mean years of education were 12.74 (SD=3.02). There were 40 whites (80%) and 10 blacks (20%).

Group 2 (Matched) was used for cross-validation analyses, as well as for comparisons with the CHI group. These subjects were individually matched to CHI subjects on age, education, gender, and race variables. The age and education categories of the WAIS-R standardization sample were used to match subjects on those variables. Group 2 (Matched) consisted of 25 subjects with a mean age of 26.3 years (SD=8.38). Ages ranged from 18 to 46 years. Mean education was 12.80 years (SD=1.76). There were 14 males (56%) and 11 females (44%). Twenty-one were white (84%) and 4 were black (16%).
**Clinical Sample**

The clinical sample, Group 3 (CHI), included patients referred for neuropsychological evaluation to a private psychology clinic in southern Louisiana. Only severe CHI patients within one year post injury were included. Severity of CHI was defined according to the Russell and Smith (1961) criteria of post-traumatic amnesia (PTA) greater than 24 hours. PTA is defined as coma plus the period of confusion following the comatose state until the recovery of continuous memory. Subjects who reported a history of drug and/or alcohol abuse according to DSM III-R criteria (APA, 1987) or neurological disorders prior to their head injury were excluded. Group 3 (CHI) included 25 individuals ranging in age from 18 to 45 years, with a mean age of 27.0 (SD=8.91). Mean years of education was 12.76 (SD=1.94). Gender and racial composition paralleled Group 2 (14 males, 11 females; 21 white, 4 black).

A summary of the demographic characteristics of the three groups appears in Table 1. There were no significant differences between the CHI and matched control groups on any demographic variables (age $t_{(48)}$=-0.28, ns; education, $t=0.08$, ns; occupation, $t=0.71$, ns).

**Materials**

Non-clinical subjects were administered a medical and psychological screening questionnaire to assess the presence of any factors which could possibly affect intellectual
Table 1

Demographic Characteristics of the Subject Groups

<table>
<thead>
<tr>
<th>Variable</th>
<th>Development</th>
<th>Matched</th>
<th>CHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Subjects</td>
<td>50</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>Age (Years)</td>
<td>42.38 (18.79)</td>
<td>26.32 (8.38)</td>
<td>27.00 (8.91)</td>
</tr>
<tr>
<td>Education (Years)</td>
<td>12.74 (3.02)</td>
<td>12.80 (1.76)</td>
<td>12.76 (1.94)</td>
</tr>
<tr>
<td>Occupation (1-6)</td>
<td>3.84 (1.22)</td>
<td>3.88 (1.20)</td>
<td>3.64 (1.19)</td>
</tr>
<tr>
<td>Gender</td>
<td>50% male</td>
<td>56% male</td>
<td>56% male</td>
</tr>
<tr>
<td>Race</td>
<td>80% white</td>
<td>84% white</td>
<td>84% white</td>
</tr>
<tr>
<td>Residence</td>
<td>100% urban</td>
<td>100% urban</td>
<td>100% urban</td>
</tr>
<tr>
<td>Region</td>
<td>100% south</td>
<td>100% south</td>
<td>100% south</td>
</tr>
</tbody>
</table>

Note. Group 2 and Group 3 did not significantly differ on any demographic variables.
functioning (see Appendix A). All subject groups completed the following measures:

**Wechsler Adult Intelligence Scale - Revised** (WAIS-R; Wechsler, 1981). The WAIS-R is an individually administered measure of intellectual functioning consisting of six verbal and five performance subtests. The verbal subtests include Information, Digit Span, Vocabulary, Arithmetic, Comprehension, and Similarities. The performance subtests are Picture Completion, Picture Arrangement, Block Design, Object Assembly, and Digit Symbol. The WAIS-R was administered and scored in the standard way outlined in the manual (Wechsler, 1981). Raw scores for each subtest were converted to a scale score with a mean of 10 and a standard deviation of 3. Scale scores were summed and converted to age-normed Verbal, Performance, and Full Scale IQs.

**National Adult Reading Test** (NART; Nelson, 1982). The NART is an individually administered single word reading test consisting of 50 words listed in order of difficulty. The NART word list was administered in the manner outlined by Nelson and O’Connell (1978). The number of errors (incorrect pronunciations and words not attempted) were recorded. Correct responses were determined by using the pronunciations given in *Webster’s Encyclopedic Unabridged Dictionary of the English Language* (1989).
Procedure

Non-clinical Subjects

Each subject was individually assessed in a single session lasting approximately two and a half hours. A brief interview was conducted with each potential subject. At this time the project was explained, and demographic and medical screening data were obtained. A consent form explaining the study was completed by those subjects meeting the participation criteria. All chosen subjects then completed the WAIS-R and the NART.

Clinical Subjects

Data from closed head injured patients were obtained from routine neuropsychological evaluations. Demographic data, as well as medical history, were obtained from clinical interview information. The WAIS-R had been administered as part of the neuropsychological evaluation. At the completion of the evaluation, the present study was explained and a consent form was completed for those subjects wishing to participate. The NART was then administered.

Data Analyses

Study 1

A Pearson Product Moment correlation between obtained WAIS-R IQs and corresponding estimated NART IQs was calculated for the Group 2 (Matched) subjects to test for significant correlations as proposed by Hypothesis 1. A
series of independent one-tailed t-tests comparing obtained WAIS-R IQs and estimated NART IQs for Group 3 (CHI) and Group 2 (Matched) was used to test for significant between group differences as stated in Hypothesis 2. To test Hypothesis 3, a discrepancy score (D-score) was determined for each subject by calculating the absolute value of the difference between the estimated NART IQ and the corresponding obtained WAIS-R IQ. There were three such discrepancy scores: NART FSIQ D-score, NART VIQ D-score, and NART PIQ D-score. Significant differences between the D-scores for Group 3 (CHI) and Group 2 (Matched) were assessed by a series of independent one-tailed t-tests.

**Study 2**

Using Group 1 (Development) subjects, three separate regression analyses were conducted using in turn the WAIS-R FSIQ, VIQ, and PIQ as the dependent variable and the NART error score and corresponding Barona et al. (1984) estimated IQ score as the independent variables. A Pearson Product Moment correlation between obtained WAIS-R IQs and corresponding estimated combined NART-Barona IQs was calculated for the Group 2 (Matched) subjects to test for significant correlations as proposed by Hypothesis 1.

Independent one-tailed t-tests comparing obtained WAIS-R IQs and estimated combined NART-Barona IQs for Group 3 (CHI) and Group 2 (Matched) were used to test for
significant between group differences as stated in Hypothesis 2.

To test Hypothesis 3, discrepancy scores (D-scores) representing the absolute value of the difference between estimated NART-Barona IQs and the corresponding obtained WAIS-R IQs were calculated for unimpaired Group 2 (Matched) subjects. There were three such discrepancy scores: NART-Barona FSIQ D-score, NART-Barona VIQ D-score, and NART-Barona PIQ D-score. Significant differences between the D-scores for Group 3 (CHI) and Group 2 (Matched) were assessed by a series of independent one-tailed t-tests.

Dependent samples one-tailed t-tests were used to compare the discrepancy scores for the three estimation methods for the unimpaired control sample, as stated in Hypothesis 4. The D-scores for the combined NART-Barona method and the NART estimation method (Ryan & Paolo, 1992) were those previously calculated. Discrepancy scores representing the absolute value of the difference between estimated Barona IQs and the corresponding obtained WAIS-R IQs were calculated for unimpaired Group 2 (Matched) subjects. There were three such discrepancy scores: Barona FSIQ D-score, Barona VIQ D-score, and Barona PIQ D-score. One-tailed dependent measures t-tests were used to compare the FSIQ discrepancy scores for the three estimation methods. Similar analyses were conducted for VIQ and PIQ D-scores.
Results

Study 1

The Ryan and Paolo (1992) regression equations to estimate WAIS-R FSIQ, VIQ, and PIQ using NART error score were cross-validated on two groups, non-impaired adults below age 75 and CHI patients.

Hypothesis 1

Estimated NART IQs were calculated and correlated with the corresponding obtained WAIS-R IQs first for each non-impaired group separately, and then for the total sample of non-impaired subjects. Obtained WAIS-R IQs and estimated NART IQs were significantly correlated in unimpaired subjects, as proposed by Hypothesis 1.

The means, standard deviations, and correlation coefficients between obtained WAIS-R IQs and estimated NART IQs for the Group 1 (Development) sample are presented in Table 2. Correlations between estimated NART IQs and obtained WAIS-R IQs were .84, .85, and .74 for FSIQ, VIQ, and PIQ, respectively. All correlations were highly significant (p<.0001).

As with the Group 1 (Development) sample, there were significant correlations between obtained WAIS-R IQs and NART estimated IQs for the non-impaired Group 2 (Matched) subjects: FSIQ .84, VIQ .71, and PIQ .76 (all p’s<.0001).
Table 2

Obtained and Estimated WAIS-R IQs for Group 1 (Development) Sample

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Correlation with WAIS-R IQ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Obtained IQs:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAIS-R FSIQ</td>
<td>98.82</td>
<td>16.57</td>
<td></td>
</tr>
<tr>
<td>WAIS-R VIQ</td>
<td>98.22</td>
<td>16.74</td>
<td></td>
</tr>
<tr>
<td>WAIS-R PIQ</td>
<td>99.86</td>
<td>15.48</td>
<td></td>
</tr>
<tr>
<td><strong>Estimated IQs:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryan and Paolo (1992)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART FSIQ</td>
<td>102.12</td>
<td>13.15</td>
<td>.84*</td>
</tr>
<tr>
<td>NART VIQ</td>
<td>101.08</td>
<td>13.62</td>
<td>.85*</td>
</tr>
<tr>
<td>NART PIQ</td>
<td>101.64</td>
<td>9.63</td>
<td>.74*</td>
</tr>
<tr>
<td>Barona et al. (1984)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barona FSIQ</td>
<td>101.75</td>
<td>10.41</td>
<td>.75*</td>
</tr>
<tr>
<td>Barona VIQ</td>
<td>103.02</td>
<td>10.48</td>
<td>.77*</td>
</tr>
<tr>
<td>Barona PIQ</td>
<td>101.64</td>
<td>9.83</td>
<td>.66*</td>
</tr>
</tbody>
</table>

*p<.0001
The two groups of non-impaired subjects were combined (n=75) and correlations between WAIS-R IQs and the corresponding estimated NART IQs were calculated. As with the separate groups, significant correlations were found for this larger group of non-impaired subjects. Correlations between obtained WAIS-R IQs and estimated NART IQs were .84, .82, and .75 for FSIQ, VIQ, and PIQ, respectively (p<.0001). These correlations are comparable to those found with elderly adults age 75 years and older (Ryan & Paolo, 1992), suggesting that the NART regression equations function consistently for normal elderly adults as well as unimpaired adults below 75 years of age.

**Hypothesis 2**

The NART equations were also validated by comparing obtained WAIS-R IQs and estimated NART IQs for CHI subjects and non-impaired subjects matched for age, education, gender, and race. Results of independent t-tests confirmed Hypothesis 2, showing that obtained WAIS-R IQs were significantly lower in the CHI group than in a matched (age, education, gender, race) control group; while estimated NART IQs for CHI patients and matched unimpaired controls did not differ significantly.

The number of errors on the NART for Group 2 (Matched) ranged from 10 to 43, with a mean of 27.88 (SD=9.22). For Group 3 (CHI), the mean was 28.20 (SD=8.19), with a range of 14 to 44. NART error scores for non-impaired and CHI
subjects were not significantly different ($t(48)=0.13$, ns), demonstrating the stability of NART performance in severe CHI patients.

The means and standard deviations of obtained WAIS-R IQs, estimated NART IQs (Ryan & Paolo, 1992) and estimated Barona IQs (Barona et al., 1984) IQs for Group 3 (CHI) and Group 2 (Matched) are presented in Table 3. There were significant differences between the groups for WAIS-R FSIQ ($t(48)=3.46$, $p<.002$); WAIS-R VIQ ($t(48)=2.64$, $p<.01$); and WAIS-R PIQ ($t(48)=4.12$, $p<.0002$). No group differences were found for either the estimated NART IQs (NART FSIQ, $t(48)=0.13$, ns; NART VIQ, $t(48)=0.13$, ns; NART PIQ, $t(48)=0.13$, ns) or the estimated Barona IQs (Barona FSIQ, $t(48)=0.31$, ns; Barona VIQ, $t(48)=0.32$, ns; Barona PIQ, $t(48)=0.28$, ns). This is in accordance with the previously determined equivalency between the two groups on demographic variables and NART error scores.

**Hypothesis 3**

To further assess the clinical validity of the Ryan and Paolo (1992) NART regression equations, discrepancy scores (D-scores) were calculated and compared for Group 3 (CHI) and Group 2 (Matched). There were three such discrepancy scores (NART FSIQ D-score, NART VIQ D-score, and NART PIQ D-score) representing the absolute value of the difference between the estimated NART IQ and the corresponding obtained WAIS-R IQ (see Table 4).
Table 3
Means and Standard Deviations of Obtained and Estimated IQs

<table>
<thead>
<tr>
<th>Variable</th>
<th>Matched</th>
<th>CHI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Obtained IQs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WAIS-R FSIQ</td>
<td>96.20</td>
<td>10.98</td>
</tr>
<tr>
<td>WAIS-R VIQ</td>
<td>96.56</td>
<td>11.03</td>
</tr>
<tr>
<td>WAIS-R PIQ</td>
<td>96.48</td>
<td>11.50</td>
</tr>
<tr>
<td>Estimated IQs:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryan and Paolo (1992)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART FSIQ</td>
<td>100.05a</td>
<td>10.36</td>
</tr>
<tr>
<td>NART VIQ</td>
<td>99.94</td>
<td>11.77</td>
</tr>
<tr>
<td>NART PIQ</td>
<td>100.12a</td>
<td>8.31</td>
</tr>
<tr>
<td>Barona et al. (1984)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barona FSIQ</td>
<td>101.96a</td>
<td>7.23</td>
</tr>
<tr>
<td>Barona VIQ</td>
<td>101.95a</td>
<td>7.14</td>
</tr>
<tr>
<td>Barona PIQ</td>
<td>100.91</td>
<td>6.26</td>
</tr>
<tr>
<td>Combined Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART-Barona FSIQ</td>
<td>99.66</td>
<td>10.84</td>
</tr>
<tr>
<td>NART-Barona VIQ</td>
<td>97.04</td>
<td>10.87</td>
</tr>
<tr>
<td>NART-Barona PIQ</td>
<td>98.89</td>
<td>9.16</td>
</tr>
</tbody>
</table>

* p<.01, **p<.002, ***p<.0002
*Formula estimated IQ differs from the corresponding actual WAIS-R IQ, p<.05
Table 4
Discrepancies Between Obtained and Estimated WAIS-R IQ

<table>
<thead>
<tr>
<th>Group</th>
<th>Matched</th>
<th>CHI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D-score</td>
<td>Mean</td>
</tr>
<tr>
<td>Estimation Method:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ryan and Paolo (1992)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART FSIQ</td>
<td>6.22</td>
<td>3.39</td>
</tr>
<tr>
<td>NART VIQ</td>
<td>7.46</td>
<td>4.66</td>
</tr>
<tr>
<td>NART PIQ</td>
<td>6.34</td>
<td>5.24</td>
</tr>
<tr>
<td>Barona et al. (1984)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barona FSIQ</td>
<td>8.99a</td>
<td>6.68</td>
</tr>
<tr>
<td>Barona VIQ</td>
<td>8.64a</td>
<td>5.84</td>
</tr>
<tr>
<td>Barona PIQ</td>
<td>8.33a</td>
<td>8.61</td>
</tr>
<tr>
<td>Combined Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART-Barona FSIQ</td>
<td>5.42</td>
<td>3.15</td>
</tr>
<tr>
<td>NART-Barona VIQ</td>
<td>6.20</td>
<td>3.90</td>
</tr>
<tr>
<td>NART-Barona PIQ</td>
<td>5.88</td>
<td>5.81</td>
</tr>
</tbody>
</table>

Note. Independent t-test comparisons between CHI and Matched Controls, *p<.05, **p<.0001
^D-score significantly differs from the corresponding NART-Barona D-score, p<.05
Hypothesis 3 was confirmed by a series of independent t-tests. There was significantly more discrepancy between estimated NART and obtained WAIS-R IQs for the CHI subjects than for the non-impaired matched subjects.

Mean NART FSIQ D-score was 6.22 (SD=3.39) for non-impaired group and 14.65 (SD=7.48) for the CHI group, (t(48)=5.13, p<.0001). Similar results were found for NART VIQ D-score (t(48)=2.34, p<.02) and NART PIQ D-score (t(48)=6.44, p<.0001). These significant NART IQ D-score differences suggest that obtained WAIS-R IQs were markedly decreased from premorbid levels after closed head injury and confirm the clinical utility of NART performance as a measure of premorbid intelligence.

Study 2

Regression equations to estimate WAIS-R IQs were developed by combining a stable measure of performance (NART) with the Barona et al. (1984) demographic regression equation. Demographic variables were used to compute the Barona et al. (1984) estimated IQ, which was entered as a predictor variable along with NART error score in the multiple regression analysis. Separate linear regression analyses were performed with the Group 1 (Development) sample to generate formulas to estimate WAIS-R FSIQ, WAIS-R VIQ, and WAIS-R PIQ. In each case, the dependent measure was the obtained WAIS-R IQ, while the independent measures were the corresponding Barona IQ and NART error score.
Before generating the combined regression equations, the applicability of using the Barona et al. (1984) regression equations for the Group 1 (Development) sample was ascertained by cross-validation of the Barona et al. (1984) formulas. Obtained WAIS-R IQs were regressed on the predictor variables of the Barona et al. (1984) equations. This predicted Barona IQ was then correlated with the actual IQ computed from the Barona et al. (1984) regression equations. The correlations were .97 for FSIQ, .98 for VIQ, and .93 for PIQ. All correlations were significant beyond p < .0001, showing that the Barona et al. (1984) estimated IQs were appropriate independent variables for this study.

The use of individual demographic variables combined with NART error score for the generation of new regression equations was also investigated. In a stepwise regression analysis, obtained WAIS-R IQs were regressed on the demographic variables used by the Barona et al. (1984) study (age, education, sex, race, occupation, region, and residence) and the NART error score. None of the demographic variables entered into final regression equations after NART error score. The individual predictive value of the demographic variables in determining premorbid IQ did not add significantly to the variance accounted for by the NART error score. However, when these demographic variables were combined in the Barona et al. (1984) regression equations, their predictive value was
significant. The individual predictive value of the demographic variables in determining premorbid IQ may not have been significant because the heterogeneity of the standardization sample of the WAIS-R used to develop the Barona et al. (1984) regression equations could not be practically duplicated in this study. Any demographically based method for estimating IQ would yield low correlations when applied to demographically homogeneous samples; whereas higher correlations would be observed for samples that are more demographically diverse.

The following combined regression equations to estimate premorbid intelligence were then generated using Barona IQ and NART error score as predictor variables.

\[
\text{NART-Barona FSIQ} = 75.3933 + .4577(\text{Barona FSIQ}) - .8880(\text{NART errors})
\]

\[
\text{NART-Barona VIQ} = 69.2886 + .5020(\text{Barona VIQ}) - .8749(\text{NART errors})
\]

\[
\text{NART-Barona PIQ} = 79.5881 + .3993(\text{Barona PIQ}) - .7638(\text{NART errors})
\]

Standard errors of estimate were 8.56, 8.39, and 10.34 for NART-Barona FSIQ, VIQ, and PIQ, respectively. The correlation between obtained WAIS-R IQs and estimated NART-Barona IQs were as follows: FSIQ .86, VIQ .87, PIQ .76 (all \( p \)'s < .0001).

Table 5 presents the variance accounted for, the standard error of estimate (SEE) and the range of possible
Table 5
Comparison of WAIS-R Estimation Methods in Three Studies

<table>
<thead>
<tr>
<th>Estimation Method</th>
<th>R²</th>
<th>SEE</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ryan and Paolo (1992)a</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART FSIQ</td>
<td>.55</td>
<td>8.83</td>
<td>75 - 131</td>
</tr>
<tr>
<td>NART VIQ</td>
<td>.61</td>
<td>7.70</td>
<td>74 - 132</td>
</tr>
<tr>
<td>NART PIQ</td>
<td>.32</td>
<td>12.08</td>
<td>82 - 123</td>
</tr>
<tr>
<td>Barona et al. (1984)b</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barona FSIQ</td>
<td>.36</td>
<td>12.14</td>
<td>69 - 120</td>
</tr>
<tr>
<td>Barona VIQ</td>
<td>.24</td>
<td>11.79</td>
<td>69 - 120</td>
</tr>
<tr>
<td>Barona PIQ</td>
<td>.38</td>
<td>13.23</td>
<td>74 - 116</td>
</tr>
<tr>
<td>Combined Method (1994)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NART-Barona FSIQ</td>
<td>.74</td>
<td>8.56</td>
<td>62 - 130</td>
</tr>
<tr>
<td>NART-Barona VIP</td>
<td>.76</td>
<td>8.39</td>
<td>60 - 130</td>
</tr>
<tr>
<td>NART-Barona PIQ</td>
<td>.57</td>
<td>10.34</td>
<td>71 - 126</td>
</tr>
</tbody>
</table>

scores from the Barona et al. (1984) demographic study, the Ryan and Paolo (1992) present abilities study and the combined NART-Barona method. As can be seen in Table 5, the combined NART-Barona regression equations accounted for considerably more variance than did either the demographic or present ability estimation methods: 74.39\% for FSIQ, 75.90\% for VIQ, and 57.19\% for PIQ. The standard errors of estimation for the combined NART-Barona regression equations were comparable to those of the NART equations and smaller than those for the Barona et al. (1984) equations.

A much wider range of estimated IQ scores was possible with the combined NART-Barona method than with either the NART (Ryan & Paolo, 1992) or Barona et al. (1984) methods. The combined NART-Barona FSIQ estimation range was 12 points greater than the NART FSIQ range and 17 points greater than the range of the Barona FSIQs. For VIQ estimation, the combined NART-Barona range was 12 points larger than that for the NART VIQs and 19 points larger than the Barona VIQ range. For PIQ estimation, the combined NART-Barona range was 14 points larger than that of the NART PIQ scores and 13 points larger than the Barona PIQ range.

**Hypothesis 1**

For the Group 2 (Matched) cross-validation sample, the correlation between obtained WAIS-R IQs and the combined NART-Barona estimated IQs were .87, .76, and .79 for FSIQ, VIQ, and PIQ, respectively, p<.001). These correlations
were comparable to those of the Group 1 (Development) sample and supported the hypothesis that obtained WAIS-R IQs and estimated NART-Barona IQs would be significantly correlated in unimpaired subjects.

**Hypothesis 2**

The clinical utility of the new equations was evaluated using the Group 3 (CHI) and Group 2 (Matched) samples. As stated previously, there were significant differences between obtained WAIS-R IQs for the CHI and matched unimpaired subjects (WAIS-R FSIQ ($t(48)=3.46, p<.002$); WAIS-R VIQ ($t(48)=2.64, p<.01$); and WAIS-R PIQ ($t(48)=4.12, p<.0002$). However, the IQs estimated with the NART-Barona equations were not significantly different for the two groups (NART-Barona FSIQ, $t(48)=.31$, ns; NART-Barona VIQ, $t(48)=.32$, ns; NART-Barona PIQ, $t(48)=.30$, ns) (see Table 3). Results of these independent $t$-tests confirmed Hypothesis 2, showing that obtained WAIS-R IQs were significantly lower in the CHI group than in a matched control group; while estimated NART-Barona IQs for CHI patients and matched unimpaired controls did not differ significantly.

**Hypothesis 3**

To further assess the relation between estimated IQ and current intellectual functioning, D-scores were calculated for the NART-Barona equations. There were three D-scores for the NART-Barona estimation method (NART-Barona FSIQ D-
score, NART-Barona VIQ D-score, and NART-Barona PIQ D-score) representing the absolute value of the difference between the estimated NART-Barona IQ and the corresponding obtained WAIS-R IQ.

Hypothesis 3 was confirmed by a series of independent t-tests. There was significantly more discrepancy between estimated NART-Barona IQ and obtained WAIS-R IQs for the CHI subjects than for the non-impaired matched subjects. Mean NART-Barona FSIQ D-score was 5.42 (SD=3.15) for non-impaired group and 12.32 (SD=6.68) for the CHI group, \( (t(48)=4.67, \ p<.0001) \). Similar results were found for NART-Barona VIQ D-score \( (t(48)=1.97, \ p<.05) \) and NART-Barona PIQ D-score \( (t(48)=5.68, \ p<.0001) \). These significant NART-Barona IQ D-score differences suggest that obtained WAIS-R IQs were markedly decreased from premorbid levels after closed head injury and confirm the clinical utility of the NART-Barona formulas to estimate premorbid intelligence.

**Hypothesis 4**

Dependent samples one-tailed t-tests were used to test the hypothesis that for unimpaired control subjects the discrepancy between obtained WAIS-R IQs and the IQs estimated using the NART-Barona formula would be significantly less than the discrepancies found when WAIS-R IQ was estimated using either the NART IQ equations (Ryan & Paolo, 1992) or the Barona IQ equations (Barona et al., 1984). The D-scores for the combined NART-Barona method and
the NART estimation method (Ryan & Paolo, 1992) were those previously calculated. Discrepancy scores representing the absolute value of the difference between estimated Barona IQs and the corresponding obtained WAIS-R IQs were calculated for unimpaired Group 2 (Matched) subjects. There were three such discrepancy scores: Barona FSIQ D-score, Barona VIQ D-score, and Barona PIQ D-score.

For nonimpaired Group 2 (Matched) subjects, the difference between the obtained WAIS-R FSIQ and the estimated NART-Barona FSIQ (NART-Barona FSIQ D-score) was significantly less than the difference between obtained WAIS-R FSIQ and estimated FSIQ using the Barona et al. (1984) equation (Barona FSIQ D-score). The NART-Barona FSIQ D-score and the NART FSIQ D-score were not significantly different from each other. Mean combined NART-Barona FSIQ D-score was 5.42, compared to 8.99 for Barona FSIQ D-score ($t(24)=2.91$, $p<.01$) and 6.22 for NART FSIQ D-score ($t(24)=1.16$, ns).

The combined NART-Barona equation for estimating VIQ also resulted in less discrepancy between estimated and obtained WAIS-R IQ (NART-Barona VIQ D-score) than the Barona et al. (1984) method, and did not differ significantly when the Ryan and Paolo (1992) method was employed. The mean difference between obtained WAIS-R VIQ and estimated combined NART-Barona VIQ (NART-Barona VIQ D-score) was 6.20,
compared to 8.64 for the Barona VIQ D-score ($t(24)=2.18$, $p<.05$) and 7.46 for the NART VIQ D-score ($t(24)=1.40$, ns).

For WAIS-R PIQ estimation, the difference between obtained and estimated PIQ score was significantly less using the combined NART-Barona equation (NART-Barona PIQ D-score) than when the Barona et al. (1984) equation was employed. The discrepancy score for the combined NART-Barona method did not differ significantly from that using the NART estimation method. The mean difference between obtained WAIS-R PIQ and estimated NART-Barona PIQ (NART-Barona PIQ D-score) was 5.88, compared to 8.33 for the Barona PIQ D-score ($t(24)=2.29$, $p<.05$) and 6.34 for the NART PIQ D-score ($t(24)=0.95$, ns).

In summary, the combined NART-Barona IQ estimation method was significantly more accurate in estimating WAIS-R FSIQ, WAIS-R VIQ, and WAIS-R PIQ scores than the Barona et al. (1984) equations as hypothesized. However, the combined NART-Barona IQ estimation method was not significantly different from the Ryan and Paolo (1992) NART estimation method in estimating WAIS-R IQ scores.
CHAPTER IV

Discussion

The identification of intellectual decline is an important aspect of neuropsychological assessment. Methods for determining premorbid intellectual ability in those patients who do not have premorbid intellectual data available are needed in order to document the decline of intellectual functioning for diagnosis as well as for setting goals for rehabilitation. There are currently two main approaches to the estimation of premorbid intelligence, the present abilities method and the demographic method. The first study in this project demonstrated that NART performance was a valid present abilities measure for the estimation of premorbid intelligence. The second study in this project demonstrated that more accurate estimation of WAIS-R IQs was possible using regression equations that combined the demographic and present abilities approaches.

In Study 1, the regression equations developed by Ryan and Paolo (1992) to estimate WAIS-R IQs from NART performance using normal elderly adults over the age of 75 years were cross-validated for non-impaired subjects below age 75. Obtained WAIS-R IQs and estimated NART IQs were significantly correlated in unimpaired subjects, as proposed by Hypothesis 1. The significant correlations between obtained WAIS-R IQs and NART estimated IQs indicate that in younger adults there exists a strong relation between the
ability to read irregular words and current intellectual functioning. This finding is consistent with previous research which demonstrated that NART error score can reliably be used to estimate intellectual functioning in neurologically sound persons below 75 years of age (Hart et al., 1986; Nelson & O’Connell, 1987; Sharpe & O’Carroll, 1991).

The NART equations were also validated by comparing obtained WAIS-R IQs and estimated NART IQs for CHI subjects and non-impaired subjects matched for age, education, gender, and race. NART error scores for non-impaired and CHI subjects were not significantly different, demonstrating the stability of NART performance in severe CHI patients. Hypothesis 2 was confirmed, showing that obtained WAIS-R IQs were significantly lower in the CHI group than in a matched (age, education, gender, race) control group; while estimated NART IQs for CHI patients and matched unimpaired controls did not differ significantly.

There was significantly more discrepancy between estimated NART and obtained WAIS-R IQs for the CHI subjects than for the non-impaired matched subjects, as proposed by Hypothesis 3, suggesting a marked deterioration from a higher premorbid level for CHI subjects. These results from Study 1 concur with previous research that has shown that NART performance is resistant to cerebral dysfunction and is
a useful "present abilities" estimate of premorbid intelligence (Crawford, Parker, & Besson, 1988).

The combination of the present abilities and demographic variables in regression equations has been suggested as a means to provide a more accurate estimate of premorbid IQ (Bolter et al., 1982; Stebbins et al., 1990). In the second study, a combined demographic and present abilities regression equation to estimate WAIS-R IQs was developed and cross-validated on neurologically intact subjects. Regression equations to estimate WAIS-R IQs were developed by combining a stable measure of performance (NART) with the Barona et al. (1984) demographic regression equation. Demographic variables were used to compute the Barona et al. (1984) estimated IQ, which was entered as a predictor variable along with NART error score in the multiple regression analysis. Separate linear regression analyses were performed with the Group 1 (Development) sample to generate formulas to estimate WAIS-R FSIQ, WAIS-R VIQ, and WAIS-R PIQ. In each case, the dependent measure was the obtained WAIS-R IQ, while the independent measures were the corresponding Barona IQ and NART error score.

As proposed in Hypothesis 1, significant correlations between obtained WAIS-R IQs and the combined NART-Barona estimated IQs were found for the cross-validation sample. These correlations were comparable to those of the development sample and supported the hypothesis that
obtained WAIS-R IQs and estimated NART-Barona IQs would be significantly correlated in unimpaired subjects.

The NART-Barona equations were also validated by comparing obtained WAIS-R IQs and estimated NART-Barona IQs for CHI subjects and non-impaired subjects matched for age, education, gender, and race. As proposed in Hypothesis 2, obtained WAIS-R IQs were significantly lower in the CHI group than in the matched control group; while estimated NART-Barona IQs for CHI patients and matched unimpaired controls did not differ significantly.

The clinical utility of the new equations was further evaluated by comparing discrepancies between estimated IQ and current intellectual functioning for CHI subjects and matched unimpaired controls. There was significantly more discrepancy between estimated NART-Barona IQ and obtained WAIS-R IQs for the CHI subjects than for the non-impaired matched subjects, as proposed in Hypothesis 3. These significant NART-Barona IQ D-score differences suggest that obtained WAIS-R IQs were markedly decreased from premorbid levels after closed head injury and confirm the clinical utility of the NART-Barona formulas to estimate premorbid intelligence.

The accuracy of estimated WAIS-R IQs using the NART-Barona formula was compared to the accuracy of the NART IQ equations (Ryan & Paolo, 1992) and the Barona IQ equations (Barona et al., 1984). Hypothesis 4 was partially confirmed
in that the combined NART-Barona IQ estimation method was significantly more accurate in estimating WAIS-R FSIQ, WAIS-R VIQ, and WAIS-R PIQ scores than the Barona et al. (1984) equations as hypothesized. However, the combined NART-Barona IQ estimation method was not significantly different from the Ryan and Paolo (1992) NART estimation method in estimating WAIS-R IQ scores.

In summary, the combination of the demographic and present abilities approaches to the estimation of premorbid intelligence may be more useful than when the approaches are used separately. When the Barona IQ and NART error score were both included as predictor variables, the combined NART-Barona IQ equations accounted for more variance than that reported for equations based on demographic variables or NART performance alone. The percent of variance accounted for by these combined NART-Barona Index equations was comparable with that found by Crawford, Stewart et al. (1989) for the estimation of WAIS scores from the NART and demographic variables. Furthermore, the standard errors of estimate associated with the NART-Barona IQ regression equations were similar to those of the NART IQ equations, and approximately 70 percent less than those of the Barona IQ equations, therefore providing a more accurate WAIS-R IQ estimate.

A weakness of both the Barona et al. (1984) and Ryan and Paolo (1992) equations is that the range of possible
estimated scores predicted by these equations is generally quite restrictive; subjects whose IQ scores deviate more than one standard deviation from the mean are likely to suffer from significant under- or over-estimation. For both formulas, in order for scores to be predicted into the upper and lower IQ ranges, extreme and specific demographic and/or NART scores are required. While the NART estimation formula extended the ceiling on estimated WAIS-R IQ scores above that of the Barona estimation formula, complete inability to read correctly any words on the NART still results in estimated WAIS-R FSIQ and WAIS-R VIQ within the Borderline range (75 and 74, respectively) and WAIS-R PIQ within the Low Average range (82). The combined NART-Barona Index regression formulas expand the range of possible estimated WAIS-R IQs, maintaining the high scores possible from the NART formulas while extending the limit of possible low estimated IQ scores. For individuals in High Average and Borderline ranges of intellectual functioning, the NART-Barona regression formulas may reduce the under- and overestimation, respectively of premorbid intelligence.

The improvement of WAIS-R IQ estimation with the addition of a present abilities measure to the Barona et al. (1984) demographic estimation of WAIS-R IQ may have corrected limitations that reduced the accuracy of these demographic formulas. The addition of a reading measure that is highly correlated with intelligence may have
compensated for differences in education not recognized by the Barona formulas. For example, the same education category code is given to an individual with a bachelor's degree as to someone with an advanced degree. Also, a person with 12 years of special education or a GED receives the same education code as someone who completes 12 years of education in advanced classes. Another limitation involves overachievers and underachievers. Thus, the NART may compensate for sources of error within the educational and occupational categories.

For research applications, the NART-Barona regression equations should be most useful for studies requiring group comparisons of premorbid WAIS-R IQ, especially with CHI populations. Language deficits are rarely exhibited after diffuse brain injury, therefore the combined NART-Barona method to estimate WAIS-R IQ scores should function similarly for the more common mild CHI (McKinlay & Gray, 1992). Before the combined NART-Barona Index equations can be used in a clinical setting, validation studies are needed for a variety of clinical populations including demented subjects, other neurologically impaired groups, and patients with psychiatric disorders. Additionally, retrospective validation of the combined NART-Barona Index equations using neurologically impaired subjects with actual premorbid WAIS-R IQ scores would help determine the accuracy of these estimation formulas. Until such additional studies validate
the use of the combined demographic and present abilities estimation method, they may not be used with confidence for the determination of intellectual impairment due to cerebral dysfunction.
REFERENCES


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Matarazzo, J. D. (1972). Wechsler’s measurement and appraisal of adult intelligence (5th ed.). Baltimore: Williams & Wilkins.


APPENDIX A

Medical and Psychological Screening for Control Subjects

Subject # ___________ Date ___________

1. Have you ever been hospitalized or received medical attention for an infection involving the brain, spinal cord, or other nerves?

2. Have you ever been treated or hospitalized for high blood pressure, heart problems, stroke or other blood circulatory problems?

3. Have you ever been hospitalized or treated for a head injury of any type?

4. Have you ever been knocked unconscious? If yes, for how long were you unconscious?

5. Have you experienced a brief loss of awareness?

6. Have you ever experienced sudden uncontrollable body tremors, muscle twitches, or convulsions?

7. Have you ever been treated for diabetes, glandular problems, vitamin deficiencies, or any other problem related to body chemistry?

8. Have you ever been diagnosed with a brain tumor or other malformation of the brain?

9. Have you ever received treatment for any neurological or psychiatric disorder?

10. Are you currently, or have you in the past, ever seen a mental health professional for personal difficulties?

11. Do you experience excessive daytime sleepiness or other sleep-related difficulties?

12. Have you ever received treatment, either inpatient or outpatient, for alcohol or drug abuse?

13. Do you have now, or have had in the past, any other medical or psychological problems that have not been addressed?

NOTE: Affirmative answers to any of the above questions will be explored in greater detail to determine if the subject has evidence of a condition warranting exclusion from the study.
APPENDIX B

Informed Consent - Control Subjects

The psychology department at Louisiana State University is conducting a study in order to develop a method of estimating prior levels of intellectual functioning, before the onset of neurological injury or disease. We are asking for volunteers to complete the Wechsler Adult Intelligence Scale - Revised and the National Adult Reading Test. In addition, participants in this study will be asked to fill out a medical screening questionnaire. The information obtained will enable us to develop formulas to estimate levels of intellectual functioning. The accuracy of these estimation equations will be determined by comparing head injured patients to those without neurological dysfunction. The primary investigators of this project include Sandra C. Friedberg, M.S. and W. Drew Gouvier, Ph.D.

All information collected in this study will be kept strictly confidential. Information obtained in this project will be used only in conjunction with this study and participants will remain anonymous. Participation is voluntary and will require approximately two and a half hours. You may withdraw from the study at any time and your questions will be answered to your satisfaction. You may at any time choose not to answer a question if you do not wish to answer it. Results of the study will be furnished by mail upon request.

Participant Signature ___________________ Date ____________

Name ________________________________

Witness Signature _____________________
APPENDIX C

Informed Consent - CHI Subjects

The psychology department at Louisiana State University is conducting a study in order to develop a method of estimating prior levels of intellectual functioning, before the onset of neurological injury or disease. The primary investigations of this project include Sandra C. Friedberg, M.S. and W. Drew Gouvier, Ph.D. This study involves the examination of your neuropsychological test results pertaining to intellectual functioning, and completion of reading test lasting about fifteen minutes.

All information collected in this study will be kept strictly confidential. Information obtained in this project will be used only in conjunction with this study and participants will remain anonymous. Participation is voluntary and you may withdraw from the study at any time. Your questions regarding this study will be answered to your satisfaction. Results of the study will be furnished by mail upon request.

Participant Signature ___________________________ Date ________________

Name __________________________________________

Witness Signature _______________________________
APPENDIX D

The National Adult Reading Test (NART)

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VITA

Sandra Cook Friedberg, daughter of Derrell A. Cook, Sr. and Theresa N. Cook, was born in Lafayette, Louisiana on August 14, 1950. She graduated from Cathedral-Carmel High School in Lafayette, Louisiana. She received a Bachelor of Science degree with a major in Accounting from the University of Southwestern Louisiana in 1972. She received a Master of Science degree with a major in Psychology from the University of Southwestern Louisiana in 1986.

In addition to being a member of the honor societies of Phi Kappa Phi, Phi Chi, Alpha Lambda Delta, and Gamma Beta Phi, she received the LSU Alumni Association Fellowship from 1989 to 1993. Professional affiliations include the American Psychological Association, Division 40 of the American Psychological Association, and the National Academy of Neuropsychologists.

Sandra is married to Frank T. "Ted" Friedberg, Ph.D. and is the mother of three children, James H. Dupuis, Jr., Patrick C. Dupuis, and Michael E. Dupuis.
Candidate: Sandra Cook Friedberg

Major Field: Psychology

Title of Dissertation: Estimation of Premorbid Intelligence: A Combined Demographic and Psychometric Approach

Approved:

[Signatures]

Major Professor and Chairman
Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

July 13, 1994