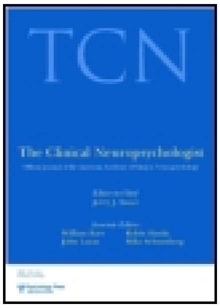


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# Influence of Demographic Variables on Neuropsychological Test Performance after Traumatic Brain Injury*

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## ABSTRACT

The validity of correcting for demographic variables when considering neuropsychological test scores was evaluated in a sample of 136 patients with traumatic brain injury (TBI) who had been screened carefully for premorbid or comorbid confounding factors. When considered in concert with neurological variables, age and education accounted for a significant proportion of the variance in raw scores on the Category Test and the Trail Making Test in the complete sample. Gender did not affect level of test performance. Correcting neuropsychological test scores for demographic variables did not significantly alter their success in identifying patients with severe TBI, but did lead to greater accuracy when classifying individuals with mild-moderate TBI. This investigation concluded that norms that consider the demographic background of the individual are likely to reflect more accurately the neuropsychological status of patients with TBI than interpretations that are based exclusively on raw data.

The practical importance of demographic corrections in the clinical evaluation of neuropsychological test results has been a matter of considerable debate in recent years. Heaton, Grant, and Matthews (1991) presented normative data for many test measures that were stratified by age, gender, and level of education, based on healthy individuals. Despite disagreements about some of the statistical foundations of the methods involved (Fastenau & Adams, 1996; Heaton, Matthews, Grant, & Avitable, 1996), the Heaton et al. (1991) norms found rapid and widespread application. This appeared to be consistent with the results of several prior studies that suggested that age and education in particular had marked effects on neuropsychological test performance (Bornstein & Suga, 1988; Leckliter & Matarazzo, 1989). Moses, Pritchard and Adams (1999) recently demonstrated that the Heaton et al. (1991) norms were largely successful in minimizing the effects of age and educational level on neuropsychological test scores in a large mixed sample.

Despite the popularity of the Heaton et al. (1991) norms, Reitan and Wolfson (1995) have asserted that adjusting raw neuropsychological test scores according to demographic background may not be a valid procedure when evaluating individuals with brain impairment. They based this conclusion on the fact that they found minimal effects of age and education when a group of 50 individuals with documented brain impairment was split up into either older and younger participants, or those with higher versus lower levels of education. However, their conclusions were seriously challenged by several authors (Shuttleworth-Jordan, 1997; Vanderploeg, Axelrod, Sherer, Scott, & Adams, 1997), primarily because of methodological flaws such as failure to keep constant one variable (age,

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education, or severity of brain impairment) when investigating the effects of any of them individually.

Most of the above-mentioned disagreements have focused on the classification of the presence or absence of brain impairment in heterogeneous diagnostic samples. The goal of the current investigation was to compare the relative accuracy of uncorrected and demographically corrected neuropsychological test scores in the classification of the degree of brain impairment in individuals with a single diagnosis, traumatic brain injury (TBI). It has been well established that TBI can result in significant neuropsychological sequelae. Deficits in speed of information processing and novel problem-solving are common, particularly with increasing injury severity such as prolonged coma (Dikmen, Machamer, Winn, & Temkin, 1995; Gale, Johnson, Bigler, & Blatter, 1995; Katz & Alexander, 1994). The spectrum of TBI severity, ranging from mild to severe, offers the opportunity to consider levels of impairment instead of the dichotomy of presence versus absence of impairment. Reitan and Wolfson (1997) reported that the effects of age and education on neuropsychological status in persons with mild TBI were minimal. However, their study was hampered by very small sample sizes (consistently contrasting subgroups of 10 participants or less), leading to insufficient evidence to reject the null hypothesis.

We planned to compare, in a sufficiently large sample of individuals with TBI, the relative accuracy of classification of neuropsychological impairment related to two levels of injury severity (established independently on the basis of neurological criteria) when using two different normative systems for neuropsychological test results: the neuropsychological deficit scale (NDS) developed by Reitan and Wolfson (1993) and the demographically corrected norms (DCN) developed by Heaton et al. (1991). It has been established that severe TBI is frequently associated with long-term neuropsychological impairment, whereas the vast majority of patients with mild TBI have a complete resolution of cognitive symptoms within one to three months (Alexander, 1995; Binder, Rohling, & Larrabee, 1997). For this reason, we expected any classification system to find much more frequent impairment in a severe injury group than in a mild-moderate injury group.

Because a flexible battery approach was used at the facility where this study was conducted, it was decided a priori to focus attention on two tests: the Trail Making Test (TMT; Reitan & Wolfson, 1993) and the booklet version of the Category Test (CAT; DeFilippis & McCampbell, 1979). These two tests were selected because they measure skills such as speeded performance (TMT) and problem-solving (CAT) that are often affected by TBI, and because they had been included in the majority of the eligible evaluations that were considered during the time period for which retrospective data for this study were available.

Much of the previous research appeared to support the assumption that age and education may have significant effects on neuropsychological test performance (Bornstein & Suga, 1988; Heaton et al., 1996; Leckliter & Matarazzo, 1989; Moses et al., 1999; Vanderploeg et al., 1997). Although some gender differences have been reported on measures of sensory and motor abilities, previous research has not shown that gender is of significant influence on tests like the CAT and TMT (Heaton, Ryan, Grant, & Matthews, 1996). For these reasons, the following two hypotheses were formulated. Hypothesis (1) was that age and education, but not gender, would explain a significant degree of the variance in the raw neuropsychological test scores of the entire TBI sample (i.e., above and beyond that accounted for by injury severity). Hypothesis (2) was that the DCN system would yield a higher classification accuracy than the NDS system when discriminating between individuals with severe versus mild-moderate TBI.

## METHOD

### Participants

Approval for retrospective chart review was obtained from the Research Committee of the regional Mid-Western rehabilitation facility where this study was conducted. The 136 participants were selected from a 6-year series of consecutive inpatient and outpatient referrals, on the basis of the following criteria: (1) diagnosis of TBI through an external force to the head, with associated alteration of consciousness; (2) psychometric assessment with the CAT, the TMT, and the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981) within one year after injury (the latter test was included to obtain measures of psychometric intelligence as an indication of general level of cognitive functioning); (3) aged between 20 and 74 years (to allow applicability of all available norms); (4) absence of any prior neurological, psychiatric, special education, or substance abuse history; and (5) absence at the time of assessment of any litigation, compensation-seeking or other factors that might have confounded or invalidated the test results (e.g., severe uncorrected visual impairment, non-English language fluency, etc.). Only first evaluations (no repeat evaluations) were included.

The final sample included 71 men and 65 women. Most participants ($n$ = 126) were Caucasian, with 5 African-American, 3 Latino-American, and 2 Asian-American participants. The majority ($n$ = 82) had been drivers in motor vehicle accidents. Other injury circumstances included the following: pedestrians who were struck by motor vehicles ($n$ = 17), motor vehicle passengers ($n$ = 13), falls ($n$ = 12), and other ($n$ = 12). On average, participants were assessed at 93.12 days after injury ($SD$ = 78.95).

Various measures of injury severity were considered. The duration of post-traumatic amnesia was determined to be unreliable due to the need for retrospective estimation on the basis of patient report in many cases. Although Glasgow Coma Scale (GCS; Teasdale & Jennett, 1974) scores could be reconstructed from the records for the vast majority of the participants, these scores tended to be quite variable during the first 24 hr after injury, leading to unstable classifications. However, duration of coma (defined as the number of days until the patient gave a meaningful response to verbal commands) could be reliably ascertained from all available records. For this reason, and in order to have sufficient numbers of participants in each subgroup, the total sample was divided into two subgroups, based on whether or not participants had at least one day of coma. There were 96 participants in the mild-moderate group and 40 participants in the severe group. Median length of coma was 5 days (range 1-35) in the latter group. The majority of participants in that group also had CT or MRI evidence for diffuse ($n$ = 28) and/or focal ($n$ = 25) intracranial lesions.

We gave consideration to the possibility of dividing the sample in half, based on the median level of age or education, consistent with some prior studies (Reitan & Wolfson, 1995; Vanderploeg et al., 1997). However, this would have resulted in unequal distributions of injury severity across groups. For example, severe injuries (with coma of at least one day) tended to occur predominantly in younger participants, an observation that has also been documented previously (Wiegner & Donders, 1999a). For this reason, we only contrasted subgroups based on injury severity but we also performed some regression analyses using the complete sample.

**Procedure**

The CAT, TMT, and WAIS-R were administered in a standardized manner as part of neuropsychological evaluations that had been requested in the context of rehabilitation. Assessments were performed only when participants were medically stable and could recall meaningful information from day to day.

**Data Analyses**

Scores on the neuropsychological tests were classified as being in the impaired or the unimpaired range on the basis of both the NDS and the DCN systems. This method was chosen because the NDS system is based on ordinal categories which cannot be analyzed as continuous variables. In order to have comparable categories for the DCN system, its scores were also dichotomized. Using the NDS classification, CAT raw total error scores > 45, TMT Part A (TMTA) total seconds > 39, and TMT Part B (TMTB) total seconds > 85 were considered to be indicative of impairment (Reitan & Wolfson, 1993). The DCN system is based on $T$ scores ($M$ = 50, $SD$ = 10), with higher scores reflecting better performance. Although Heaton et al. (1991) originally suggested a tentative cut-off point of $T$ = 40 for consideration of impairment, convention with other test instruments such as the WAIS-R (Wechsler, 1981) has been to use a more conservative criterion, such as scores at or below the 10th percentile, as an indication of below-average performance. Consequently, we considered CAT, TMTA, and TMTB $T$ scores < 38 to reflect impairment with the DCN system.

## RESULTS

The neuropsychological test scores and the demographic characteristics of primary interest are presented in Table 1 for the complete sample and separately for both injury severity groups. There were no statistically significant differences between the two groups in terms of injury circumstances, time since injury, or the proportion of ethnic minorities ($p > .10$ on all variables). There was a trend for individuals in the severe group to be somewhat younger than those in the mild-moderate group, but this fell short of statistical significance, $F$ (1, 134) = 3.48, $p < .10$. The group difference in gender distribution was not statistically significant, $\chi^2$ (1, $N$ = 136) = 2.41, *ns*. The groups were very similar in level of education, $F$ (1, 134) = .62, *ns*. As would be expected, the severe group consistently did worse than the mild-moderate group on all psychometric measures (this trend was not analyzed for statistical significance because of the nonrandom group assignment). The severe group also demonstrated a pattern of relatively worse Performance IQ than Verbal IQ – $t$ (38) = 2.72, $p < .01$ – which is a common phenomenon after such injuries (Crawford, Johnson, Mychalkiw, & Moore, 1997).

In order to determine the relative contribution of neurological and demographic variables on psychometric test performance, we first performed three stepwise regression analyses with (as the dependent variables), respectively, the raw scores on CAT (in errors) and TMTA and TMTB (in seconds), using the complete sample. The independent variables were the same in each of these three analyses: coma (defined as present or not present for at least one day, because of the very skewed distribution as a continuous variable), presence or absence of an intracranial lesion on CT or MRI scan, age at assessment, education, and gender. In light of the exploratory nature of these analyses, it was determined a priori that a somewhat liberal level of alpha (.10) would be used as the criterion to retain variables in the final models.

The same three-variable regression model was found for CAT, $F$ (3, 132) = 8.70, $p <$

Table 1. Demographic Characteristics and Psychometric Measures in the Complete Sample, and for Subgroups with Mild-Moderate ($n$ = 96) and Severe ($n$ = 40) Traumatic Brain Injury.

| | Complete | | Mild-Moderate | | Severe | |
|---|---|---|---|---|---|---|
| | *n* | (%) | *n* | (%) | *n* | (%) |
| Gender | | | | | | |
| Man | 71 | (52) | 46 | (48) | 25 | (63) |
| Woman | 65 | (48) | 50 | (52) | 15 | (37) |
| Ethnicity | | | | | | |
| Caucasian | 126 | (93) | 90 | (94) | 36 | (90) |
| Other | 10 | (7) | 6 | (6) | 4 | (10) |
| Injury circumstances | | | | | | |
| Motor vehicle driver | 82 | (60) | 60 | (62) | 22 | (55) |
| Other | 54 | (40) | 36 | (38) | 18 | (45) |
| | *M* | (*SD*) | *M* | (*SD*) | *M* | (*SD*) |
| Age (years) | 35.27 | (12.29) | 36.58 | (12.33) | 32.10 | (11.73) |
| Education (years) | 13.20 | (2.13) | 13.29 | (2.11) | 12.98 | (2.19) |
| Time since injury (days) | 93.12 | (78.95) | 97.35 | (85.58) | 82.95 | (59.87) |
| Category Test (errors) | 57.86 | (31.44) | 53.15 | (31.71) | 69.18 | (28.03) |
| Trail Making Test, Part A (seconds) | 38.10 | (20.46) | 33.95 | (17.23) | 48.08 | (24.10) |
| Trail Making Test, Part B (seconds) | 94.51 | (56.48) | 77.31 | (39.84) | 135.78 | (68.56) |
| Verbal IQ (standard score) | 93.87 | (11.84) | 95.98 | (11.28) | 88.80 | (11.74) |
| Performance IQ (standard score) | 93.76 | (14.00) | 97.79 | (11.76) | 83.08 | (14.31) |

.0001; TMTA, $F$ (3, 132) = 9.76, $p < .0001$; and TMTB, $F$ (3, 132) = 22.72, $p < .0001$. These findings are presented in Table 2. As can be seen in this table, coma, age, and education all affected raw performance on all three measures. However, the impact of the combined demographic variables was relatively greater than that of coma on CAT, whereas the reverse pattern occurred for TMTB. Partial effect sizes ranged from very small (impact of age on TMTA) to large (impact of coma on TMTB).

We then performed two separate logistic regression analyses to determine to what extent the NDS and DCN systems could accurately assign participants to the mild-moderate or severe groups, based on their combined CAT, TMTA, and TMTB scores. For this purpose, severity groups ($n = 2$) were used as the dependent variable, and the CAT, TMTA, and TMTB scores (with each score dichotomized as being in the impaired or unimpaired range) as independent variables. Separate analyses were run for the NDS and DCN systems. These findings are presented in Table 3. Examination of this table suggests that the NDS and DCN were approximately equal in their ability to identify neuropsychological impairment associated with severe brain injury when it was present, but that the NDS misclassified relatively more individuals with mild-moderate injuries in this regard, leading to a lower overall classification accuracy. This difference was statistically significant, Sign test = 5.5, $p < .01$.

In order to investigate the possibility that the NDS might actually be picking up on persisting ''true'' organic impairment that was missed by the DCN, a post hoc informal analysis was performed of the characteristics of the 12 participants from the mild-moderate group who were classified into the severe group by the NDS but not by the DCN. The majority of these individuals ($n = 8$) were actually cases of uncomplicated mild head trauma (i.e., with unequivocal documentation of duration of loss of consciousness < 30 min, duration of post-traumatic amnesia < 24 hr, and no evidence for intracranial lesions on CT or MRI scan) who were evaluated more than 3 months post injury. Thus, it is unlikely that the NDS system was, in fact, more accurate in its sensitivity to residual brain compromise than the DCN system.

## DISCUSSION

The purpose of this investigation was to compare the relative accuracy of the NDS and DCN systems in the classification of severity of impairment in a large, carefully selected group of patients with TBI. Hypothesis (1) was confirmed: age and education explained a significant proportion of the variance in raw scores on the selected neuropsychological tests in the complete sample, even when taking into account neurological injury variables (especially presence of prolonged coma). As was expected, gender did not significantly affect performance on the selected neuropsychological measures. Hypothesis (2) was also confirmed: although the NDS and DCN systems demonstrated approximately equal accuracy in the classification of patients with neuropsychological impairment as

Table 2. Regression Models for Raw Neuropsychological Test Scores in the Complete Sample.

| Variable | Partial $R^2$ | | |
|---|---|---|---|
| | CAT | TMTA | TMTB |
| Coma | .06** | .10* | .22* |
| Age | .06** | .02*** | .04** |
| Education | .05** | .06** | .08* |

*Note.* CAT = Category Test; TMTA = Trail Making Test, Part A; TMTB = Trail Making Test, Part B.
* $p < .001$; ** $p < .01$; *** $p < .10$.

Table 3. Classification Accuracy Using Demographically Adjusted vs. Non-Adjusted Scores for Combination of Category Test and Trail Making Test (Parts A and B).

| | Percent Correctly Classified | | |
|---|---|---|---|
| | Mild-Moderate | Severe | Total Sample |
| NDS | 67 | 70 | 68 |
| DCN | 79 | 73 | 77 |

*Note.* NDS = neuropsychological deficit scale; DCN = demographically corrected norms.



the result of severe TBI, the latter system had relatively superior accuracy when classifying individuals with mild-moderate TBI.

The fact that both injury severity (presence of coma for at least one day) and demographic variables (education and, to a lesser extent, age) affected performance on both the CAT and the TMT is consistent with the results from various prior studies that suggested that demographic characteristics need to be considered in concert with neurological variables in clinical samples (Moses et al., 1999; Vanderploeg et al., 1997; Wiegner & Donders, 1999b). It is important to realize that these results were obtained in a sample that did not include many elderly people. Although we had used an upper age limit of 74 in the selection criteria, the oldest participant was actually 65 years of age. This was primarily due to the presence of complicating prior medical histories in many of the older potential participants. Furthermore, the influence of education was apparent even though potential participants with special education histories had been excluded from this sample, and only 10% of the sample had less than high school education. Thus, age and education effects on neuropsychological test performance do not occur just at the extreme ends of the spectrum in patients with TBI. At the same time, more research is needed to examine the effects of demographic variables in previously healthy older adults with TBI, and particularly those with lower levels of education.

Combined demographic variables accounted for relatively more of the variance in CAT raw scores than did injury severity, whereas the opposite pattern was found for the TMT (especially part B). This finding is consistent with the fact that TBI tends primarily to affect performance on speeded tasks (Dikmen et al., 1995; Hawkins, 1998; Martin, Donders, & Thompson, in press). It is possible that some patients with TBI may be able to profit from the structure provided by the format of the CAT, while being less efficient under time pressure on the TMT.

The current findings support the conclusion by Moses et al. (1999) that use of the norms developed by Heaton et al. (1991) represents an advance over interpretations of raw neuropsychological test scores that are not corrected for demographic variables. The relative advantage of the DCN system appears to be primarily in the reduction of the likelihood of classifying a patient as having persisting neuropsychological impairment whereas, in fact, none might exist. This may be particularly important in the evaluation of individuals with mild TBI, especially when complicating factors such as litigation are present (Binder & Rohling, 1996).

It is also important to realize that neither the DCN system nor the NDS system yielded a perfect classification of participants in terms of neurological injury severity. Given the fact that we used the 10th percentile as the cut score for defining impairment, one might expect approximately 10% of normals to be misclassified. However, the best overall classification accuracy in this study was less than 80%. This may be due in part to the fact that a fairly stringent criterion for determining severity (length of coma of at least one day) was used. Typically, one would also obtain additional neuropsychological measures (e.g., memory tests) in clinical evaluations. Furthermore, recovery after TBI tends to be variable across the entire range of injury severity, as reflected in the slightly higher than average variances for some of the psychometric variables that were employed in this study (e.g., *SD* = 12.51 for TMTB *T* scores). At the same time, these findings reflect the importance of considering neuropsychological test scores within the context of the entire history, clinical presentation, and psychosocial circumstances of the patient. In other words, neuropsychological test scores should never be interpreted in isolation, no matter what instruments or normative systems are being used.

Possible limitations of this investigation must also be considered. We did not include a control group and can therefore make no determination regarding the classification of either normative system in persons without any brain injury. The vast majority of our participants were Caucasian, and replication with a more ethnically diverse sample is desirable. Although we were able to consider the presence or absence of intracranial lesions, we did not have the technology required to perform morphometric analyses of neuroimaging data, which have been shown to be predictive of performance on psychometric tests after TBI (Johnson, Bigler, Burr, & Blatter, 1994). Therefore, the results from our study do not provide information about the degree to which lesion volume interacts with demographic variables in determining performance on the CAT or TMT in patients with TBI. Another consideration is that this was a sample of convenience that was retrospectively recruited. The reasons why some patients were not administered the CAT or TMT could not be reconstructed in many cases. However, the relative strengths of this investigation are that the sample was carefully screened for confounding premorbid or comorbid factors, and that a sufficiently broad range of injury severities was obtained that excluded restriction of range effects.

With these considerations in mind, the findings from this investigation suggest that performance on neuropsychological tests like the CAT and TMT after TBI in individuals between the ages of 20 and 65 years is affected by both demographic variables and injury variables. Reliance on norms that do not take into consideration the patient's age and education is not supported by these data. At the same time, it must be acknowledged that there are some residual concerns about exactly how accurate the demographic corrections in the Heaton et al. (1991) norms are, even when it is clear that they represent an improvement over interpretations that are based on raw scores alone (Fastenau, 1998; Moses et al., 1999). This just reflects the fact that adequate neuropsychological assessment requires more than actuarial classification of individuals as impaired versus not impaired. Information about demographic effects on recently developed tests that were standardized on large, representative samples such as the Wechsler Adult Intelligence Scale-Third Edition (Wechsler, 1997a) and Wechsler Memory Scale-Third Edition (Wechsler, 1997b), with sufficient cell sizes for different combinations of age and education, would be extremely helpful in this regard. Future research is also needed to examine the predictive validity of demographically corrected scores with regard to educational or vocational outcome after TBI.

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