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Profiles of cognitive functioning in chronic spinal cord injury and the role of moderating variables

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Abstract

A traumatic spinal cord injury (SCI) is accompanied by a documented moderate to severe head injury in significant numbers of SCI patients. In a previous study (Dowler et al., 1995), cognitive deficits were found in 41% of the SCI individuals who were studied with a chronic injury from a traumatic event. The present study investigated whether clinically useful subtypes of normal and impaired cognition could be identified in a chronic ($M = 17$ years postinjury) SCI sample using a cluster analysis of neuropsychological test performance. A battery of 16 neuropsychological tests was administered to 91 SCI patients and 75 control participants. Composite scores, reflecting performance in different cognitive domains, were derived from a factor analysis of the battery, and these scores were then used in the cluster analysis. A six-cluster solution generated the most distinct and clinically relevant SCI group profiles. Two of the cognitive profiles were characterized by normal functioning in all cognitive domains, but they were distinguished by differences in performance levels. The remaining four SCI groups (60% of the sample) showed clinically significant deficits in one or more cognitive domains, with different groups showing moderate attention and processing speed deficits, mild deficits in processing speed, executive processing difficulties, or moderate memory impairments. Though age and premorbid intellectual ability were strong predictors of the cognitive profiles of some SCI groups, when these factors were controlled, the findings suggested that the patterns of cognitive impairment were likely due to a potential concomitant head injury. (*JINS*, 1997, *3*, 464–472.)

Keywords: Spinal cord injury, Neuropsychology, Head injury

INTRODUCTION

Spinal cord injury (SCI) most commonly results from a rapid acceleration–deceleration event such as a motor vehicle accident or a fall (Stover et al., 1986), and frequently is accompanied by a head injury. Unfortunately, a mild or moderate head injury sustained under these circumstances may be overlooked in the acute care setting (Narayan et al., 1990), because of the primary focus on attending to the problems directly associated with the SCI. Davidoff and colleagues (1985) reported that posttraumatic amnesia (PTA) frequently went unassessed in the emergency room. They found that only 22% of SCI patients were evaluated routinely for PTA, and 91% of these individuals showed PTA of at least 24 hr. In another study (Davidoff et al., 1988), PTA lasting greater than 1 hr was documented in 29% of a SCI sample, with 12% of these patients showing PTA greater than 72 hr; only 56% of the SCI injuries in the study were due to a motor vehicle accident, which is more often associated with concomitant head injury. These results suggest that head injury is commonly associated with a traumatic SCI, and many are moderate or severe. Mild head injury typically does not produce enduring cognitive deficits (Levin et al., 1987; Alexander, 1995; Dikmen et al., 1995), but CT or MRI scan abnormalities may increase the possibility of cognitive deficits. Nevertheless, the incidence of CT abnormalities was low (8.2%) in a retrospective study of a large sample of mild head injury patients (1448; Borczuk, 1995), but cognitive deficits were not assessed in these patients. Moderate and severe head injury is associated with well doc-

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umented long-term deficits (Dikmen et al., 1995). The impact of such deficits is likely to be particularly profound for quadriplegic or paraplegic SCI patients, who must learn new self-care skills, and adapt to significant lifestyle and vocational changes soon after the injury, and for many years to come (Davidoff et al., 1992).

In the present study, we investigated patterns of cognitive functioning in SCI individuals who were assessed at least 1 year after the trauma that produced the SCI. Previous work has shown deficits in a broad range of cognitive domains in acute SCI patients (Roth et al., 1989), and long-term cognitive deficits have been found in 41% of an SCI sample that was evaluated an average of 17 years postinjury (Dowler et al., 1995). In this latter study, information processing speed best differentiated the SCI and the control groups when the interrelationship among the neuropsychological measures of cognitive functioning was controlled. Though these results suggested that compromised information processing speed was the primary explanation for long-term deficits in this sample, this may not accurately characterized the performance of individual SCI patients, since group means can obscure important individual differences.

The premise underlying most previous studies is that there is a unitary pattern of cognitive deficits in SCI. This makes some sense given that the frontal and the temporal poles are most vulnerable to head injury due to contusions and/or axonal shearing (e.g., for a review see Gennarelli, 1993), which might be expected to produce some common impairments. There is controversy, however, about the necessary conditions that produce axonal shearing. Primate models of head injury indicate that shearing is only likely to occur when loss of consciousness is immediate and at least 6 hours in duration (Gennarelli, 1993), which suggests that it underlies only some head injuries. Contusions are commonly associated with more localized damage, while hypoxia or anoxia occurs in some but not all head injuries, and may produce diffuse or focal damage (Lezak, 1995). This variation in mechanisms raises the possibility that, like the head injury population (Crosson et al., 1990; Malec et al., 1993), there may be identifiable subgroups of SCI patients who show distinct patterns of cognitive deficits, but who are concealed in studies that examine neuropsychological test performance exclusively in terms of group means.

There are other reasons to suspect that subgroups of people with a chronic SCI who show meaningful patterns of impaired and spared cognition could be identified. One moderator variable that contributes to the severity of cognitive deficits after mild head injury includes age, with older adults tending to show greater deficits than younger adults (Goldstein et al., 1994). In addition, alcohol consumption, emotional distress, and premorbid factors such as low education and low intellectual abilities negatively affect neuropsychological outcomes after head trauma (Kay & Silver, 1989; Dikmen et al., 1993; Malec et al., 1993).

The main goal of the present study was to determine if there are different patterns of impaired cognition in a chronic SCI sample that could be empirically derived from a cluster analysis of neuropsychological test performance. Cluster analytic techniques have been used to uncover groupings of individuals who display similar patterns of cognitive functioning in other disorders including HIV-1 (Van Gorp et al., 1993) and head injury (Crosson et al., 1990; Malec et al., 1993). As a secondary objective, we explored whether potential moderating variables (e.g., age, alcohol consumption, premorbid functioning, emotional distress) would predict subtypes of cognitive profiles in SCI patients. If reliable mediators of specific neuropsychological outcomes can be identified in chronic SCI patients, this would have implications for existing models of extended care in terms of anticipating the future need for ongoing treatment or environmental support. Finally, our study dealt with two methodological limitations of some previous work. First, the unique testing needs of the SCI sample were handled by using a nonmanual battery of tests that was sensitive to the deficits most common after head injury (Dowler et al., 1995). Second, a control group, who were well matched on extraneous variables (i.e., age, education, premorbid intellectual functioning, alcohol consumption) that could potentially confound the interpretation of impaired and normal performance, was used to derive the standardized T scores, which were used in all of the analyses.

METHOD

Research Participants

Ninety-one patients with spinal cord injury (SCI) and 75 healthy control participants volunteered for the study. The SCI participants were recruited from the Albuquerque Veterans Administration Medical Center (VAMC) and a private rehabilitation hospital in the Albuquerque area. Control participants were friends or relatives of the SCI group, or were recruited from the general medical clinic at the VAMC. SCI participants were included in the study if they had incurred their injury in a motor vehicle accident or a fall in which a concomitant head injury was probable. Retrospective documentation of a probable closed head injury (e.g., duration of loss of consciousness, retrograde and anterograde amnesia) was not possible due to the long time period between injury and evaluation (Richards et al., 1991). Similarly, CT or MRI scans were not available on most of these patients. Potential SCI participants were excluded from the study if there was a preexisting neurological, psychiatric, or alcohol abuse history prior to the SCI. The control participants had no neurologic, psychiatric, or alcohol abuse history.

All SCI participants were at least 1 year postinjury with a mean of 17 years (SD = 11.78; range = 1–57 years). Fifteen percent were quadriplegic and 85% were paraplegic or incompletely quadriplegic. Table 1 shows that there were no significant differences between the SCI and the control group in age, education level, handedness, sex, alcohol consumption (Short Michigan Alcohol Screening Test; Selzer

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Table 1. Characteristics of spinal cord injury (SCI) and control subjects[1]

Variable	SCI group	Control group
Age	46.01 (12.39)	47.27 (14.10)
Sex (% male)	91%	90%
Handedness (% right)	91%	89%
Education	13.82 (2.09)	14.35 (2.46)
WAIS–R Vocabulary[2]	45.80 (10.83)	49.82 (9.95)
WRAT–R Reading[2]	45.68 (11.88)	49.84 (9.97)
SMAST[3]	2.78 (3.14)	2.57 (3.94)

[1]Tabled values are means with standard deviations in parentheses unless otherwise specified.
[2]Tabled values are T scores using the control group's means and standard deviations from the Vocabulary subtest of the Wechsler Adult Intelligence Test–Revised (WAIS–R) and the Reading Recognition subtest of the Wide Range Achievement Test (WRAT).
[3]The measure of alcohol consumption was the Short Michigan Alcohol Screening Test (SMAST).

et al., 1975), or estimated premorbid intellectual ability (i.e., Reading Recognition subtest from the Wide Range Achievement Test–Revised; Jastak et al., 1984; Vocabulary subtest of the Wechsler Adult Intelligence Scale–Revised; Wechsler, 1981).

Procedures

Both groups were given a comprehensive neuropsychological battery that had minimal manual requirements. If the patients were quadriplegic and could not press the key required for some tests (e.g., Wisconsin Card Sort Test; WCST), the examiner pushed the key based on the patient's verbal response. Cognitive function was assessed in the areas of processing speed, memory, attention, executive functioning, and visuospatial skills. The entire test battery took approximately 2 hr to complete, and was administered in one session. The MMPI was administered in another session to assess the psychological status of the participants.

Table 2 lists the neuropsychological tests and gives the mean (standard deviation) raw scores for each group. T-score transformations were made on all of the neuropsychological test data using the means and standard deviations of the raw scores from the control group. These T scores then were used in all subsequent analyses.

RESULTS

Factor Analysis

A factor analysis was first conducted on all of the 16 neuropsychological tests, to condense the number of dependent measures used in the cluster analysis. The factor analysis also highlighted the main areas of cognitive functioning that were evaluated, thereby facilitating the interpretation of the cluster analysis. A principal components factor analysis with varimax rotation was performed on the data from the control and SCI groups so as to have an adequate sample size for the analysis. Table 3 shows that a five-factor solution was obtained, which accounted for 69% of the variance. This

Table 2. Raw scores on the neuropsychological tests

Neuropsychological Tests	Control *M* (*SD*)	SCI *M* (*SD*)
Symbol Digit Modalities Test (SDMT; Smith, 1973)	53.2 (12.4)	44.5 (11.5)
Stroop Test (Stroop, 1935; Golden, 1978)[1]		
Color naming	69.8 (14.0)	61.5 (15.3)
Color word	37.3 (11.4)	33.9 (9.3)
Wechsler Memory Scale (Russell, 1988; Wechsler, 1981)		
Logical Memory I (immediate)	27.4 (7.6)	25.9 (7.1)
Logical Memory II (delay)	24.1 (8.0)	51.90 (7.89)
California Verbal Learning Test (CVLT; Delis et al., 1987)		
Sum of five trials	51.7 (10.9)	48.7 (11.0)
Recall: long delay	10.7 (3.5)	10.3 (3.3)
WAIS–R Digit Span (Wechsler, 1981)	15.7 (3.7)	14.0 (4.0)
Paced Auditory Serial Addition Test (PASAT; Gronwall, 1987)[2]	121.9 (37.6)	106.8 (39.6)
Verbal Fluency (CFL; Benton et al., 1983)	42.2 (13.1)	40.5 (13.5)
WAIS–R Similarities (Wechsler, 1981)	21.9 (4.2)	20.7 (4.4)
Wisconsin Card Sort Test; categories (WCST; Heaton, 1981)	4.5 (2.1)	4.1 (2.1)
Recognition Memory for Faces (Warrington, 1984)	40.4 (5.7)	39.3 (5.3)
Facial Recognition (Benton et al., 1983)	44.8 (4.3)	44.4 (3.7)
Judgment of Line Orientation (Benton et al., 1983)	26.9 (5.3)	24.9 (4.3)
Hooper Visual Organization Test (HVOT; Hooper, 1983)	27.6 (5.4)	26.1 (2.9)

[1]The analyses used color naming minus color word for the dependent measure to obtain a direct index of interference.
[2]This measure represents the sum of Series 1 through 4.

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Table 3. Factor structure[1]

	Factors				
Neuropsychological tests	1	2	3	4	5
Logical Memory I	.83				
Logical Memory II	.87				
CVLT sum of five trials	.80				
CVLT delayed recall	.77				
WAIS–R Digit Span		.77			
Verbal Fluency (CFL)		.73			
PASAT		.64			
WAIS–R Similarities		.50			
Stroop (color naming minus interference)			.93		
Stroop (color naming)			.85		
SDMT			.45		
Line orientation				.84	
HVOT				.73	
Warrington Face Recognition					.88
Benton Facial Recognition					.75

[1]Tabled values are for the loading matrix which represents the correlation between each neuropsychological test and the factor.

table also shows that the factor structure was simple, as none of the neuropsychological tests loaded on more than one factor (i.e., a loading higher than .40 was considered significant).

Factor 1 accounted for 34% of the variance, and included measures of immediate and long-term memory. Factor 2 consisted of measures that were most reflective of attention and simultaneous processing (e.g., WAIS–R Digit Span, PASAT), though other tests that also have been associated with frontal lobe function (e.g., CFL, WAIS–R Similarities) loaded on this factor as well. To simplify the discussion of the results, however, Factor 2 will be referred to as a measure of attention. This factor explained almost 12% of the variance. Factor 3 accounted for 9% of the variance, and included measures that emphasize information processing speed. Factor 4 consisted of measures reflecting primary visuospatial and perceptual skills, and accounted for 8% of the variance. Finally, Factor 5 represented facial recognition skills, accounting for 7% of the variance.

The WCST (i.e., number of categories) did not load on any of the factors.[1] Nonetheless, this test was included as a separate variable in the cluster analysis, which will be discussed next, because it is a sensitive indicator of cognitive flexibility that was not explicitly captured by the other factors. In addition, it is likely that the problem solving skills required by the WCST could be compromised by a head injury, in which case this test might help to differentiate subgroups of individuals with a SCI.

[1]Although various measures from the WCST have been attributed to different cognitive functions, there is little empirical evidence to justify these distinctions. Moreover, contrary to clinical lore, performance measures derived from this test fail to be specifically related to area of brain damage (Anderson et al., 1991). Two of the most widely used measures are the number of perseverative errors and the number of categories achieved. Some research suggests that both measures are equally sensitive to the effects of brain damage (see Lezak, 1995). In the present study, there was no difference between the SCI and the control groups on either measure ($p > .20$). Hence, we selected the number of categories as the dependent measure because it was distributed normally in both subject groups.

Cluster Analysis

A cluster analysis was conducted next in order to determine whether subgroups of SCI subjects could be identified who showed clinically relevant and distinctive patterns of cognitive functioning. The dependent measures in the cluster analysis included the T score from the WCST and the five composite scores that were derived from the factor analysis (i.e., the mean of the T scores for each test associated with a particular factor). Ward's clustering method was used, in which squared Euclidean distances served as the proximity measure for calculating the degree of similarity among individuals with SCI on the dependent measures. Individuals are considered identical when their proximity measures reflect values of similar magnitudes. Though each clustering method has its own advantages, Ward's method was selected because it minimizes the variance within clusters, reduces the amount of overlap among clusters, and provides excellent recovery of known cluster structures (Aldenderfer & Blashfield, 1984). In addition, Ward's method is sensitive to performance levels, which is important in this study because the selection of treatment strategies and an individual's prognosis may depend on the level of cognitive functioning.

We investigated two- through seven-cluster solutions. The six-cluster solution best captured the structure because it generated the most conceptually distinct and clinically relevant group profiles. There were 23, 14, 11, 25, 10, and 8 SCI

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individuals in cluster Groups 1 through 6, respectively. Figure 1 displays the profiles for the six SCI cluster groups (filled circles) in each cognitive domain. An inspection of the standard deviation bars in this figure shows that the sample sizes of all clusters were sufficiently large that there was not undue within-group variability across the cognitive domains.

Figure 1 suggests that the SCI cluster groups differed in the pattern of performance across the different cognitive domains as well as in the level of performance. The profiles of Groups 1 and 2 appear essentially normal, but memory functioning is approximately 1 standard deviation higher in Group 1 than in Group 2. In contrast, the entire profile of Group 3 appears depressed, especially in the areas of attention and processing speed. Although patients in Group 4 show depressed processing speed, their performance in other cognitive domains appears relatively normal. Group 5 also shows normal performance in most cognitive domains, except in the area of cognitive flexibility. Finally, the profile of Group 6 is suggestive of deficits in memory and processing speed.

Moderator Variables of Cognitive Profiles

Our second objective was to investigate possible moderator variables of the cognitive profiles that emerged from the cluster analyses. There were no differences among the SCI groups in the proportion of paraplegic and quadriplegic in-

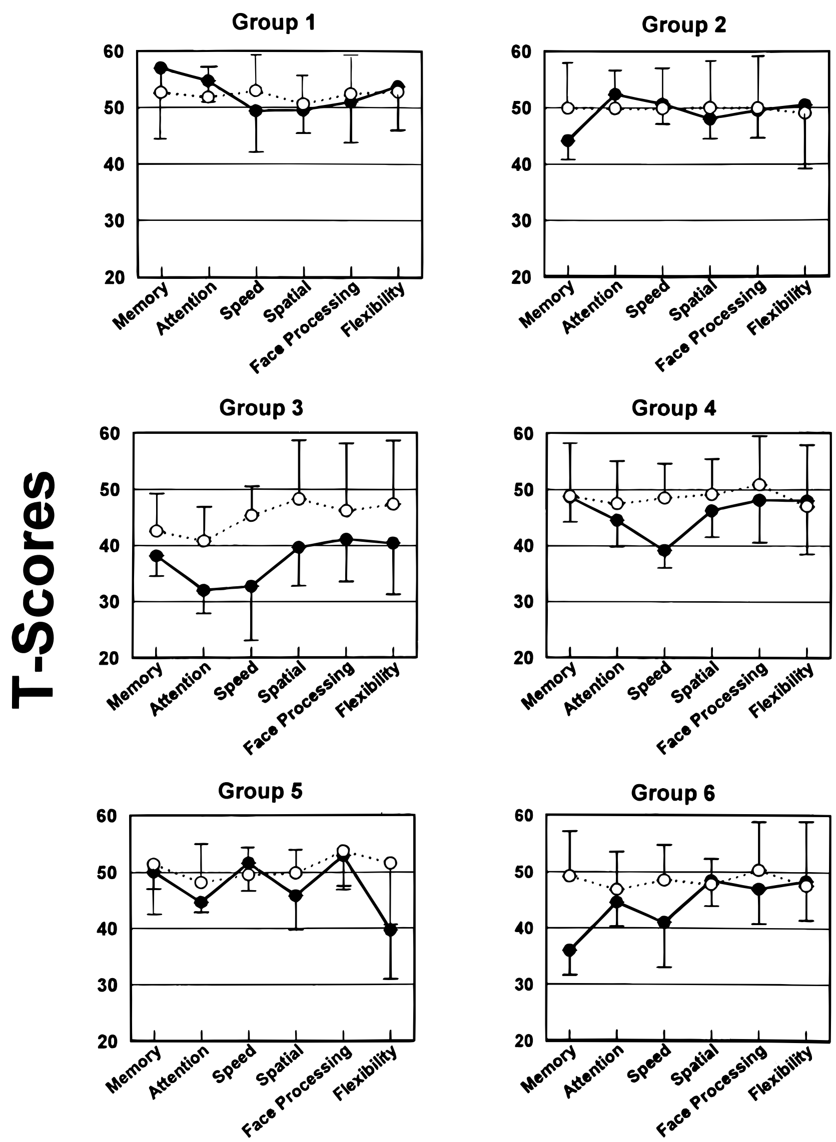

Fig. 1. Cognitive profiles of the SCI groups and subgroups of control participants. The six figures display the means (standard deviations) for each cognitive domain. Closed circles designate the means for each of the six SCI groups, which were derived from the cluster analysis. Open circles designate the means for subgroups of control participants who were of a similar age and premorbid level of functioning to their respective SCI group.

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juries (i.e., 91.3%, 92.9%, 90.9%, 75.0%, 88.9%, and 75.0% were paraplegic injuries in Groups 1 to 6, respectively; $p >$ .30 for chi-square test), so this variable was not explored further. The role of participant characteristics including age, education, alcohol consumption, years postinjury, reading recognition, and vocabulary was first examined. Table 4 displays the SCI group means on each of these variables. A stepwise discriminant function analysis using the Rao's V test statistic was conducted to identify which variable(s) best differentiated the six SCI cluster groups. This analysis controls for the intercorrelations among the dependent measures so that the resulting significant discriminator variable(s) represent those that account for the unique variance among the SCI groups.

The analysis showed that, of the six potential moderator variables, only vocabulary (Rao's V = 60.83, $p < .0001$) and age (Rao's V = 56.60, $p < .0001$) explained unique variance among the SCI groups. Forty-one percent of the SCI subjects were correctly classified on the basis of these two moderator variables. However, vocabulary and age were better predictors of actual cluster membership for some cognitive profiles than others, as they correctly classified 74%, 29%, 73%, 0%, 40%, and 50% of the subjects in cluster groups one through six, respectively. Upon examining the two cluster groups with the best classification accuracy, some interesting findings emerged. Table 4 shows that Group 1 demonstrated the highest vocabulary performance, and consisted of the youngest adults. In contrast, Group 3 consisted of the oldest adults in our SCI sample, and their vocabulary performance was almost 2 standard deviations below the mean. Though the classification accuracy for Group 6 was only 50%, this group also consisted of older adults whose vocabulary performance was in the low-normal range. These findings suggest that vocabulary, which reflects premorbid intellectual functioning, and age could potentially account for some of the differences among the SCI cluster groups in their cognitive profiles.

We also investigated whether emotional status served as a moderator variable of the cognitive profiles. An examination of each participant's L, F, and K scales indicated that all MMPI profiles were valid. A stepwise discriminant function analysis was conducted in order to identify the scale(s) that best differentiated the six SCI cluster groups. Although several scales were elevated in many of the cluster groups, the analysis showed that only Scale 8 (Rao's V = 12.89, $p < .025$) and Scale 1 (Rao's V = 12.51, $p < .05$) accounted for unique variance among the six SCI groups. However, these two scales showed low clinical predictive utility, as they correctly classified only 22% of the SCI subjects according to their cognitive profiles.

Finally, we examined whether the prediction of cognitive profiles by age and premorbid intellectual functioning could be improved by including emotional status in the discriminant function. While a stepwise discriminant function analysis showed that vocabulary (Rao's V = 60.83, $p < .0001$), age (Rao's V = 56.60, $p < .0001$), and the MMPI Scales 8 (Rao's V = 31.23, $p < .0001$) and 1 (Rao's V=18.57, $p < .01$) all accounted for unique variance among the six cluster groups, only 44% of the SCI participants were correctly classified using all four variables, which compares to 41% accurate classification using age and vocabulary only. Thus, emotional status, as assessed by the MMPI, was not a strong, unique predictor of the cognitive profiles.

Clinical Interpretation of Cluster Solutions Controlling for Moderator Variables

The analyses of moderator variables showed that a clinical interpretation of impaired and normal cognitive abilities in the SCI cluster groups must take into account the fact that some of the profiles were moderately or highly related to age and premorbid level of functioning (i.e., vocabulary ability). While the entire SCI group and control group shared similar demographic and premorbid characteristics (see Table 1), these factors varied among the six SCI cluster groups. Therefore, the entire control group was not an adequate control for most of the SCI cluster groups. To separate the bias of age and vocabulary ability from the potential

Table 4. Background characteristics and premorbid functioning of the SCI groups

	Group					
Variable	1 (*N* = 23) *M* (*SD*)	2 (*N* = 14) *M* (*SD*)	3 (*N* = 11) *M* (*SD*)	4 (*N* = 25) *M* (*SD*)	5 (*N* = 10) *M* (*SD*)	6 (*N* = 8) *M* (*SD*)
Age[1]	39.57 (9.62)	47.07 (10.77)	58.45 (13.42)	45.24 (13.15)	43.80 (5.35)	50.75 (12.78)
Education	14.65 (2.35)	14.50 (2.31)	13.45 (1.97)	13.20 (1.41)	13.00 (2.54)	13.75 (1.58)
Years postinjury	12.26 (8.05)	19.57 (14.36)	23.64 (14.69)	17.40 (11.19)	14.80 (9.54)	18.25 (13.35)
SMAST[2]	2.48 (2.63)	2.71 (2.73)	2.45 (3.11)	3.32 (3.93)	3.60 (3.57)	1.50 (1.85)
WRAT–R[3] Reading	54.20 (6.49)	48.70 (9.07)	33.36 (15.62)	45.72 (9.98)	41.67 (8.54)	37.75 (9.57)
WAIS–R[1,3] Vocabulary	54.77 (6.30)	47.86 (9.07)	31.20 (13.52)	44.55 (8.26)	43.44 (6.84)	43.34 (6.77)

[1]These variables were significant in the discriminant function analysis.
[2]Short Michigan Alcohol Screening Test
[3]Tabled values are T scores using the control group's means and standard deviations on the Vocabulary subtest of the WAIS–R and the Reading Recognition subtest from the WRAT–R.

effects of a head injury, subgroups of participants were assembled from the entire control group in order to match similar age and vocabulary distributions (i.e., *M*, *SD*, range) with each of the SCI groups. There were 45, 75, 11, 27, 10, and 26 participants in Control Groups 1 through 6, respectively. The mean (standard deviation) age was 39.2 (9.0), 47.3 (14.1), 56.0 (12.3), 46.6 (14.0), 44.0 (5.0), and 49.4 (10.2) years for Control Groups 1 through 6, respectively. The mean (standard deviation) vocabulary score was 53.1 (5.9), 49.8 (10.0), 34.1 (4.1), 41.9 (6.4), 41.3 (5.7), and 44.3 (6.3) for Control Groups 1 through 6, respectively. Control Group 2 consisted of the entire control sample, because they were well matched with SCI individuals in Group 2. The sample size in each of these control groups was as large or larger than their respective SCI group (see Table 4), so that there was a reasonable number of control cases for comparison purposes.

Figure 1 contrasts the mean level of cognitive functioning for each SCI group (closed circles) with the respective control group (open circles). This figure illustrates some of the previously documented effects of age and vocabulary proficiency on cognitive functioning in healthy individuals, especially with respect to performance levels in memory, attention, and processing speed. Profile analyses were conducted next, to test whether the cognitive profile of each SCI group was significantly different from their respective control group, who were similar in age and in premorbid level of functioning. The tests of parallelism were significant for all SCI and control group comparisons, except Group 3 [$F(5,62) = 3.68$, $p < .01$ for Group 1; $F(5,83) = 3.00$, $p < .02$ for Group 2; $F(5,46) = 3.90$, $p < .01$ for Group 4; $F(5,14) = 3.20$, $p < .05$ for Group 5; and $F(5,28) = 10.19$, $p < .001$ for Group 6]. Follow-up analyses that adjusted for type 1 errors (alpha = .01) showed that there was a trend for memory performance in the SCI individuals in Group 1 to be slightly better than their control group ($p = .018$), but in the other cognitive domains performance was within normal limits. In contrast, there was a trend for memory performance in the SCI individuals in Group 2 to be somewhat worse than their control group ($p = .014$). The SCI individuals in Group 4 were significantly impaired relative to their control group only on measures of processing speed ($p < .001$). Only WCST performance was diminished in the SCI individuals in Group 5 ($p < .01$), and both memory ($p < .001$) and processing speed ($p < .01$) were significantly impaired in the SCI individuals in Group 6. The test of parallelism was not significant when comparing the control and the SCI individuals in Group 3, but there was a significant levels effect [$F(1,20) = 14.58$, $p < .01$]. Though the latter analysis suggests that performance of SCI individuals in Group 3 was impaired across all cognitive domains, follow-up ANOVAs indicated that this was due to impairments in attention and processing speed ($p < .01$).

DISCUSSION

Earlier studies have reported deficits in most areas of cognitive functioning after an acute SCI (Roth et al., 1989; Richards et al., 1991; Davidoff et al., 1992), and in only some cognitive domains after a chronic SCI from a traumatic event (Dowler et al., 1995). The present study was designed to determine whether different patterns of cognitive functioning could be identified, long after a traumatic SCI, that were not entirely accounted for by moderator variables (age, education, alcohol use, emotional status), which can influence cognitive functioning. We also assumed that an approach that examined different patterns of cognitive functioning would be more clinically relevant, because neuropsychologists rely heavily upon the pattern of cognitive deficits and abilities when evaluating individual patients. In the present study, a cluster analysis identified six SCI groups with distinct cognitive profiles.

SCI patients in Group 1 were clearly functioning at a normal level, even when controlling for their relatively young age and high level of premorbid functioning. Though many of these individuals may not have suffered a concomitant head injury, it is also possible that some incurred a mild head injury, which, in general, would be expected to recover within 1 year (Dikmen et al., 1995). Group 2 also showed normal cognitive functioning in all domains. Although their memory performance was somewhat diminished, this clearly is not clinically significant, and likely would not negatively effect rehabilitation outcomes or psychosocial adjustment.

The remaining SCI groups displayed clinically significant impairment in one or more cognitive domains. Group 3 showed deficits in *attention and processing speed*, even when controlling for their relatively older age and lower premorbid functioning. It is possible that the attention and processing speed deficits in Group 3 were responsible for their somewhat diminished, but generally normal performance, in the other cognitive domains, since impairment in these areas can have broad effects on cognitive functioning. These deficits are consistent with reports that processing speed is particularly impaired in older adults after a head injury (Goldstein et al., 1994). However, the patients in Group 3 incurred their SCI at a similar age as the other SCI groups, so a more likely possibility is that a probable head injury could decrease an individual's level of functioning, such that the effects of normal aging are more apparent (Mortimer & Pirozzolo, 1985). Both of these explanations need to be addressed using a longitudinal research design. In addition, the findings in Group 3 are compatible with reports that lower premorbid abilities adversely affect cognitive outcomes after a head injury (Kay & Silver, 1989). Although the reasons for this finding are not entirely clear, it is thought that individuals with higher intellectual capacity have a greater ability to develop compensation strategies to reduce the functional impact of brain damage.

Group 4 showed clinically significant deficits only in the area of *processing speed*, when controlling for their relatively older age and low-normal level of premorbid functioning. Unlike Group 3, their attention and simultaneous processing skills as well as other functions associated with frontal lobe injury (e.g., verbal fluency, abstract thinking) were normal, which may partially explain why the performance of Group 4 in other cognitive domains was also intact and significantly better than that of Group 3.

Likewise, the performance of Group 5 fell within normal limits across most areas except for *cognitive flexibility,* as assessed by the WCST, which frequently is compromised after head injury (Stuss & Benson, 1986). Although impairment on the WCST has been attributed to damage to the frontal lobes (Milner, 1963), this has not always been supported (Anderson et al., 1991), which may explain why performance in Group 5 was normal in other areas that have been associated with frontal lobe function (e.g., attention, processing speed).

Only Group 6 exhibited clinically significant *memory* deficits relative to their control group. In fact, the within group variability was quite small, suggesting that memory was consistently impaired. *Processing speed* was also somewhat diminished in this group, but still fell within the low-average range. It is commonly acknowledged that complaints of memory problems from head injured patients actually reflect underlying deficits in attention, simultaneous processing and/or speed of processing (Lezak, 1995). Therefore, diminished processing speed in Group 6 could have altered memory performance on the measures used in the present study. However, it is unlikely that it accounts for the degree of memory impairments found in this SCI group, since clinically significant memory impairment was not observed in Groups 3 and 4, who also showed similar or worse processing speed deficits.

The differences between the SCI groups in their profiles of cognitive functioning is consistent with the patterns normally seen in a clinical setting in the head injury population (Gronwall, 1991), although it is important to note that cognitive impairment after a SCI could also result from processes other than head injury, such as an anoxic event from inadequate respiration (Silver et al., 1980). Head injuries vary in etiology, severity and the areas of the brain that are involved. These factors affect not only the magnitude of cognitive deficits, but also the cognitive domains that are compromised and spared. Interestingly, visuospatial and facial processing skills were relatively spared in all of the SCI groups, which is consistent with the relatively low incidence of spatial deficits after head injury (for a review, see Lezak, 1995). This finding may be due to the importance of the right parietooccipital cortex in visuospatial processing, which is less likely than the temporal or frontal lobes to be disrupted by focal damage or axonal shearing. Unfortunately, neuroimaging data were not available in the present study to determine if the groups differed in the incidence and distribution of focal lesions.

In the present study, emotional status was not an important factor in predicting the cognitive profiles of SCI patients. This finding does not discount the fact that emotional functioning, especially depression or somatic complaints, can have adverse effects on cognitive functioning. Emotional responses to catastrophic injuries are common and need to be weighed in the interpretation of neuropsychological outcomes. However, emotional status simply was not a strong, unique predictor of the patterns of cognitive functioning among SCI patients in this sample. Rather, other subject variables clearly were more powerful predictors.

What are the potential clinical implications of these findings? First, the present study reinforces the importance of obtaining a comprehensive neuropsychological assessment of individuals who have sustained a traumatic SCI, in order to rule out a possible concomitant head injury. Most importantly, these findings demonstrate that there are individual differences in the patterns of impaired and normal cognitive functioning after SCI. These patterns are clinically meaningful because they can have different implications for vocational rehabilitation, psychosocial adjustment, and long-term management of health care. For instance, individuals with memory deficits, such as in Group 6, will likely experience problems in learning new self-care skills, such as bowel and bladder care, or remembering when to shift the body in a wheelchair in order to prevent pressure sores. In contrast, impairments in cognitive flexibility will likely effect long-term adjustment in vocations that depend upon complex reasoning abilities, self-initiation skills, and efficiency.

Another significant clinical implication of the present findings is related to the fact that SCI individuals are living longer, because of the higher quality of care after injury. If a history of head injury is associated with an acceleration in the aging process, there will be a need for periodic neuropsychological evaluations together with a review of the SCI patient's medical and self-care skills, functional abilities, emotional status, and social adjustment. In addition, premorbid level of functioning must be considered in terms of anticipating these same long-term needs, especially since low premorbid functioning may decrease an individual's ability to develop strategies to compensate for cognitive impairments from a head injury.

In summary, the present results demonstrate that there are several clinically meaningful patterns of cognitive function in SCI individuals with a possible head injury. Though 40% of our sample exhibited normal cognitive functioning, one should clearly not overlook the distinct possibility of enduring cognitive impairments after a traumatic SCI. Moderate to severe head injuries frequently produce lasting cognitive deficits (Dikmen et al., 1995), which will have long-term implications for rehabilitation and treatment. The fact that a relationship exists between moderator variables and some patterns of cognitive functioning should alert clinicians to the potential longer-term consequences of a traumatic SCI when making decisions about cognitive assessment and rehabilitation.

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